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FACTORS AFFECTING RATE OF GAIN AND THEIR RELATION TO ALLOTMENT OF PIGS FOR FEEDING TRIALS[1]

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IN ALLOTTING pigs for feeding trials, the investigator tries to allot the pigs in such a way as to have in the average gain of the lots, at the end of the experiment, a measure of the influence of each treatment imposed on the pigs. To avoid confounding this influence with the effect of factors previously known to affect the rate of gain, he either "equalizes" the lots in respect to these factors or submits their effects to statistical control when analyzing the final data. The object of the present investigation was to measure the relative importance of the factors usually considered when allotting pigs for feeding trials. This would help show which factors are really essential and likely to be worth the added work and cost of "balancing" or of statistical control.

Source of Data

The data collected in the first ten years of the Record of Performance work with swine at the Iowa Agricultural Experiment Station were used in this investigation, to measure the influence of breed, litter, sex, initial weight, and previous performance on the rate of gain to an average weight of 225 lbs. Culbertson and others (1930, 1932, and 1933) describe the plan of the original experiments and the methods of feeding, management and collection of the data. Following the plan of the Danish system, four pigs from the same litter, two males and two females, were sent by farmers to be tested at the Experiment Station. Toward the end of the ten years, however, most of the pigs were from the Station herd. When more than one pig died the lot was dropped.

The lots tested during the first ten years belonged to nine breeds or to crosses between these breeds. The crossbred lots were not included in the analysis, as they were few. Also the pigs from one breed (Berkshire) which was represented by only one lot, were omitted.

The pigs were sent by farmers voluntarily and the numbers representing each breed were very irregularly distributed through the ten-year period.

The first step was to find whether the differences between years and between seasons (fall and spring) were so small that the data could be

[1] Journal Paper No. J-1352 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 402.
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analyzed as a single population without further attention to these differences between years and seasons. For measuring the differences between fall and spring pigs only the Poland China lots were used, so as not to confound seasonal differences with breed differences. It was assumed that the conclusions from these would be valid for the other breeds. An analysis of variance was made for each year. In all years except 1929 the differences between fall and spring pigs were not significant. The 1929 data showed an unusual uniformity between litters within season. We conclude that the season differences were unimportant and that the result for 1929 may be considered as an accident of sampling.

The importance of differences between years was evaluated by comparing the mean square between years with the mean square between litters within years, using each breed separately but disregarding season. Except for the Poland China pigs, the differences between years were not significant. There was no pronounced tendency for the average rates of gain for different breeds to go up or down together in successive years. The year differences in the Poland China breed may be explained, at least in part, by differences in breeding and in initial weight.

Although possibly some year-to-year and season-to-season differences may have existed, they were small enough (if indeed they were real) that it seems certain no important error was introduced by ignoring year and season in the remainder of the analysis.

Analysis

Breed

All of the data, consisting of 601 pigs in 157 litters belonging to 8 different breeds, were analyzed as a single population. Table 1 shows the analysis of variance with the interpretation of the mean squares in terms

TABLE 1. ANALYSIS OF VARIANCE IN DAILY GAIN

Source of variation	d/f	Sum of squares	Mean square	Composition of the mean square[1]
Total	600	25.769		
Between breeds	7	4.253	0.6076**	$B+3.80L+54.64G$
Between litters within breeds	149	11.190	0.0751**	$B+3.83L$
Within litters	444	10.325	0.0233	B

** Means highly significant ($P<.01$). The same symbol is used throughout this paper.

[1] $B=0.0233$ = variance between litter mates.
$L=0.0135$ = extra variance between pigs which belong to the same breed but not to the same litter.
$G=0.0098$ = extra variance between pigs belonging to different breeds.

of variance between individuals. The formulas used to compute the coefficients of the various terms in the column "composition of the mean square" are given in the footnote on page 393 of volume 3 of this JOURNAL.

The values of F are well beyond the 1 percent point of probability, indicating highly significant differences between breeds and between litters within breed. The method of analysis overestimates the effect of litter, so far as there was any real variation between years and between seasons. Most of such variation would go in the sum of squares for litters within breed. The effect of breed is thus highly significant, even when compared with an over-estimated error term.

The meaning of the variance components is shown by the following relations:

B = half the average squared difference between two litter mates

$B+L$ = half the average squared difference between two pigs which belong to the same breed but to different litters

$B+L+G$ = half the average squared difference between two pigs belonging to different breeds.

The importance of G becomes clearer when it is computed as a percentage of .0466, the total variance. G is 21 percent of this total.

From this analysis it is obvious that breed should be taken into consideration when allotting pigs for feeding trials, as 21 percent of the variance observed in these data would disappear if all pigs were from the same breed.

Litter

It is fairly well recognized that pigs from the same litter are more alike than pigs coming from different litters. Evidence on this fact was furnished by Berry and O'Brien (1921), Lush (1932, 1936), Molln (1940), and others.

The best estimate we have of the litter effect is the size of L from the analysis of variance in table 1. The litter effect was highly significant, causing about 29 percent of the total variance. If we consider only pigs from one breed, differences between litters would explain 37 percent of the variance within that breed, while other unknown causes would be responsible for 63 percent. Unquestionably pigs from the same litter are likely to gain more uniformly than pigs from different litters.

Sex

The effect of sex on the rate of gain of pigs has been studied by many investigators (Berry and O'Brien, 1921; Dunlop, 1933; Lush, 1936; Whatley, 1942; Crampton, 1941; Comstock *et al.*, 1944). All of them pointed to a small difference favoring the males but these differences seldom proved to be statistically significant.

From the sum of squares in the last line of table 1 can be separated the whole effect of sex, including any genuine interaction (I) which may exist between sex and litter. To do this the sums of squares of the comparisons between sexes were computed separately for each litter. Eliminating the sex difference in this way reduced the error term by 5.4 percent of its value.

By omitting all the incomplete lots from the data and making the analysis on an intra-breed basis, the effects of sex and of sex-litter interaction were separated, as is shown in table 2. From these results it seems that there was

TABLE 2. ANALYSIS OF VARIANCE, WITHIN BREEDS

Source of variation	d/f	Sum of squares	Mean square	Composition of the mean square
Between litters	126	9.3720	0.0744	$B+2I+4L$
Between sexes	8	0.7198	0.0900	$B+2I+33.5S$
Sex-litter interaction	126	2.6653	0.0212	$B+2I$
Within pairs of same sex	268	5.8447	0.0218	B

$$F_L = \frac{0.0744}{0.0212} = 3.52^{**} \qquad L = 0.0133$$

$$F_S = \frac{0.0900}{0.0212} = 4.25^{**} \qquad S = 0.0021$$

$$F_I = \frac{0.0218}{0.0212} = 1.03 \qquad I = -0.0003$$

$$B = 0.0218$$

no genuine sex-litter interaction. The effect of sex was highly significant statistically, although the small size of S as compared with L shows that differences in sex had less effect on gains than did differences between litters.

Initial Weight

It is well recognized that rate of gain in pigs is, to some extent, conditioned by initial weight. The usual procedure of "balancing" lots of pigs for feeding trials calls for equal initial weight of the lots. However, this requirement is important only if future gains are closely correlated with initial weights. The value of this correlation has already been estimated by a number of investigators but, as the present data were appropriate and in fairly large numbers, it was deemed advisable to compute this correlation on them.

As the data were collected from different breeds with significantly different average rates of gain and the litters were found to differ between themselves, the intra-litter correlation gives the more appropriate estimate of the correlation which tells how much is to be gained by balancing for

initial weight in addition to balancing for litter and breeds. To get this estimate, the sums of squares and products of deviation from mean were computed for each litter and pooled afterwards. This yielded a correlation coefficient equal to .24 which, for the 443 degrees of freedom available, is highly significant. The gross correlation, when the whole population was considered as a unit, was .33 ($P<.01$ for 600 d/f).

The correlations between initial weight and rate of gain reported in the literature do not agree very closely with each other nor with the values found in this investigation. Lush (1931), found an average correlation, based on the statistical equivalent of one lot of 128 pigs, of .52. Crampton and Hopkins (1934) found correlations ranging from .20 to .50, under varying conditions. This disagreement is quite natural as the correlation decreases when the length of the feeding period increases and seems to depend much on the variation in initial age and weights of the pigs when the experiment began. In these data the length of the feeding period was variable as the lots were required to reach an average weight of 225 lbs. per pig. Also the range of initial weight was small here, as the initial age varied only between 65 and 72 days.

Previous Performance

The use of a preliminary feeding period has been studied especially as a method for reducing the variability of the material to be used in the experiment. The use of such data would consist in not putting into the experimental lots those pigs whose live-weight increases during the preliminary period were very divergent from the average. The results of such practice have been disappointing, since only a little reduction in variability in the final rate of gain was obtained. Despite these results, we computed the correlation between rate of gain in the first 30 days of the feeding period and the rate of gain in the remainder of the period, in an attempt to ascertain how well this variable would predict final rate of gain. If the correlation were high it would have great usefulness, not only in the general problem of selection but also it would make possible the use of methods of allotment in which the outcome would be estimated from previous gains, without having to use subjective judgement to estimate that.

The intra-litter correlation was .32 while the gross correlation was .41. These correlations are little above the correlation with initial weight.

Discussion and Application of Results

It has been the belief of the animal husbandmen that by "balancing" the lots they were successful in decreasing the variation between lots. The

results of this investigation confirm this belief as far as "equalizing" in respect to breed, litter, sex, and initial weight is concerned. As a consequence of the effectiveness of "balancing," the variation within lots is made larger and that between lots is made smaller than it would be if the pigs were allotted at random. Consequently the variation within lots is no longer a valid error term for testing whether the treatments really produced significant differences.

Some investigators soon realized this shortcoming and devised schemes of allotment in which full advantage was taken of their ability to predict gains in swine, without invalidating the statistical analysis. Snedecor and Culbertson (1933) adapted the Latin square to animal experimentation and were quite successful in decreasing the experimental error and obtaining a valid test of significance. Dunlop (1933) tried a method in which the pigs were entered in the experiment when reaching a certain initial weight, thus eliminating the influence of this factor.

The analyses presented in this paper allow us to make some recommendations in regard to allotment of pigs for feeding trials. Some factors usually considered when pigs are allotted were studied and their relative importance as a source of variation was determined.

In an experiment designed for statistical analysis, there is no inconvenience in using pigs of different breeds, provided the design allows the elimination of this source of variation. In experiments in which the lots are simply "balanced" and only the average final gains are compared, uniformity within lots is not essential, although it is desirable. In any case the number of pigs from each breed should be the same in every lot to avoid confounding breed effects, which are not negligible, with treatment effects.

In most feeding experiments reported, litter is duly considered in the allotment and these present results commend this practice as adding to the accuracy of the results to be expected.

If the lots must be perfectly balanced with respect to litter, the number of lots is limited to the number of normal pigs in the smallest litters available. Even this number is hardly reached if other factors are to be considered. Some modern designs used in field trials, such as the incomplete block design, may be useful in overcoming this difficulty but so far we do not know of any instance in which they were tried in animal experimentation.

In relation to the large error looming in all feeding experiments, the effects of sex seem to be negligible and are hardly worth considering when allotting pigs. A little precision will be gained by considering sex, but to to do so will place more limitations on the work of the investigator. These may cost more than the precision gained will be worth. Lush (1936) and

Crampton (1941) found pronounced differences between sexes in certain carcass characteristics such as thickness of belly, thickness of back fat, and shape of ham. Crampton advises careful consideration of sex when the experiment is planned to make comparisons in carcass characteristics. This advice seems well founded.

Initial weight is a factor of much importance in allotting pigs for feeding trials only when the pigs available for the experiment range widely in initial weight. When the pigs are quite uniform in this respect, it is almost certain that the lots, even when formed at random, will not differ widely from each other in initial weight and whatever discrepancy happens to exist will be unimportant. Variations in initial weight might well be cared for, not in the allotment by the usual process of "balancing," but by statistical control. The initial weight, in every experiment, is known for each individual pig and the only extra work required for making the analysis of covariance will be some computation when the time comes for interpreting the data collected during the feeding trial. If initial weight is not considered, the work of allotment will be simplified and the investigator will have more freedom to use the available material to make a more convenient distribution in regard to other factors.

The results of this analysis do not encourage the use of a short preliminary feeding period to get an objective measure of gaining ability in pigs to be used in feeding experiments. The correlation between rate of gain in a 30-day preliminary period and final rate of gain is low and, consequently little or nothing will be gained as compared with using the subjective estimation of outcome by experienced judges.

A striking feature of this analysis is the large component of variance for error, making up nearly one-half of the total variance observed. This defines the limit of precision which can be attained by perfect allotment in respect to the factors studied. Other factors sometimes considered in allotting pigs do not seem as important as these. Consequently, we cannot hope for large decreases in the experimental error by considering other factors than those studied here. Further refinements must be sought in the techniques of feeding and management which might make litter mates of the same sex and weight gain more nearly the same, if nearly perfect precision is to be attained.

Summary

The rates of gain by 601 pigs in the Record of Performance work of the Iowa Agricultural Experiment Station were studied to determine the relative importance of breed, litter, sex, initial weight and previous performance in allotting pigs for feeding trials.

It was found that breed and litter must be carefully considered.

Differences between sexes were very small although real. Neglecting sex in the allotment will increase the experimental error only a little, except where carcass characteristics are a prime object of study.

The intra-litter correlation between initial weight and rate of gain was .24 in these data, indicating that initial weight is not important in allotment when the available pigs do not vary much in weight. Differences in initial weight might well be handled by analysis of covariance.

The intra-litter correlation between gain in a 30-day preliminary period and rate of gain in the final feeding period was .32, which is only a little more than was found for initial weight.

The large component of variance for error indicates that, although careful allotment does increase the precision of the experiment, the precision cannot become extreme even by perfect allotment. Further refinements must be sought in the techniques of feeding and management if nearly perfect precision is to be attained.

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EFFECT OF FEEDING LEVEL ON DAILY GAINS OF PIGS

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THIS study is based on the results obtained from feeding experiments conducted by the Nevada Experiment Station in cooperation with the United States Department of Agriculture[2] during the years 1925 to 1945. Experiments with 116 groups of pigs had been conducted and 95 of these were suitable to be used in this study.

A preliminary cross section chart revealed the somewhat obvious fact that there is a rather high degree of correlation between the average amount of nutrients fed per day and the daily gains of the pigs. The dots on the chart followed the regression line with reasonable consistency and it seemed that a regression equation expressing the relationship between the feeding level and daily gain, might serve as a useful tool to test the efficiency of any ration used regardless of the feeding level at which it may have been fed. That daily gains of pigs increase with the amount of feed consumed is generally recognized, but in this study an equation is submitted expressing in mathematical terms the effect of changes in feeding level on daily gains. This equation is tentative. If the idea appears to have value, one or more equations should be worked out from the composite results of several experiment stasions for it is probable that those obtained under Nevada conditions might be somewhat different from those obtained in Central United States where the bulk of the hogs is produced. In this study the digestion factors commonly used for ruminants have been used to calculate total digestible nutrients. In working up data for a revised regression equation it would probably be advisable to use digestion factors more applicable to swine.

This is not presented as a feeding standard, but it is presented as a means of evaluating the efficiency of a ration after results have been obtained.

Literature

The effect of limited rations in comparison with full feeding has been investigated by many experiment stations as cited by Morrison (1936), but no publications have been found by the author attempting to express by a mathematical equation the relationship between gains and feeding level.

There has been considerable discrepancy in the results reported by various stations when limited and full feeding have been compared as to the amount

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[2] The experiments were conducted on the Newlands Field Station, Fallon, Nevada, by the Nevada Agricultural Experiment Station in cooperation with the Division of Soils, Fertilizers and Irrigation (formerly the Division of Irrigation Agriculture), and the Bureau of Plant Industry of the U. S. Department of Agriculture.

of feed required per pound gain. Weaver (1927), Edwards (1930), and Robison (1935) found that pigs on limited rations required less concentrates per unit of gain than pigs on full feed. On the other hand, Ferrin and McCarty (1928) reported that full-fed pigs required less feed per hundred pounds gain than those on limited rations. Unpublished results of Nevada experiments show that the total digestible nutrients required per pound gain increase with the feeding level. This article, however, does not deal with that phase of the problem.

Procedure

Nearly all the experiments were started when the pigs were between 8 and 10 weeks old. Groups were fed until they had reached an average weight of 200 pounds. The experiments were conducted throughout a period of 20 years under varying seasonal conditions, and there were at times other variations in environment which would influence the results of some of the individual experiments in minor degree.

All the groups received alfalfa in some form and skimmilk in addition to concentrates. Some groups received protein supplement in addition to alfalfa and skimmilk and others did not. The experiments have been divided into four classes according to the type of ration fed, but all classes were included in determining the regression equation: (1) Pasture without extra protein, (2) Pasture with extra protein, (3) Dry lot without extra protein, and (4) Dry lot with extra protein. Feeding levels have varied from those very low in concentrates to full feeding on self feeders.

Since the quantity of total digestible nutrients consumed as alfalfa pasture could not be determined, the nutrients in alfalfa hay and alfalfa meal have also been omitted in the dry lot experiments. Therefore, the term "feeding level" as here used refers only to the nutrients in the concentrates and skimmilk.

By feeding level is meant the average total digestible nutrients fed per day (excluding roughage) divided by the mean weight per pig, and mean weight as here used was found by securing the average of the initial and final liveweights. Feeding level may be defined as percent that the total digestible nutrients fed per day is of mean weight of pigs.

Because a wide range in feeding levels was used during the course of the experiments it is possible to indicate by means of a regression equation the effect of the feeding level on daily gain.

Total digestible nutrients in the various rations were calculated by using the digestion coefficients given by Morrison (1936), on the assumption that the digestibility of concentrates by swine is not sufficiently different from that of other farm animals to invalidate the use of the same digestion factors. For this study only the concentrates and skimmilk were used in calculating

the feeding level and the alfalfa hay or pasture consumed does not enter into it. If the nutrient content of forages were included in the determination of feeding level, it would be advisable to use a digestion factor applicable to swine.

Results

A regression equation was calculated which indicates the mean daily gain obtained at any feeding level. This equation is as follows:

$$Y = .2 + .367X \qquad (1)$$

Y represents daily gain and X the feeding level.

Feeding levels, average daily gain, and average of daily gains estimated by means of the regression equation are given for each of the four classes in table 1. In figure 1, the four classifications representing types of rations are indicated by appropriate symbols.

TABLE 1. MEAN FEEDING LEVEL, DAILY GAIN, AND ESTIMATED DAILY GAIN BY KIND OF RATION

Class	Mean feeding level	Mean daily gain	Daily gain estimated from equation (1)	Mean deviation of estimate
	lbs.	*lbs.*	*lbs.*	*lbs.*
1. Pasture, no supplement	2.46	1.10	1.10	.00
2. Pasture, +supplement	2.96	1.41	1.29	−.12
3. Dry lot, no supplement	2.80	1.17	1.23	+.06
4. Dry lot, +supplement	2.97	1.30	1.29	−.01

Use of Equation

The equation may be used as a basis by which to judge the efficiency of any ration for which the data are applicable. In making comparisons between groups fed on different rations, the feeding level may be permitted to vary, but the age at starting and the final weights should be approximately the same as those used in these experiments in which the pigs were between 8 to 10 weeks old at the start and were finished at an average weight of approximately 200 pounds. The period covered by the equation is from the time of weaning to the most usual selling weight of approximately 200 pounds. Similar equations might be formulated to apply to each 4-week period of growth after weaning. It is conceivable that under some circumstances, limited rations might be most profitable in one period of the pigs' growth and full feeding at another period.

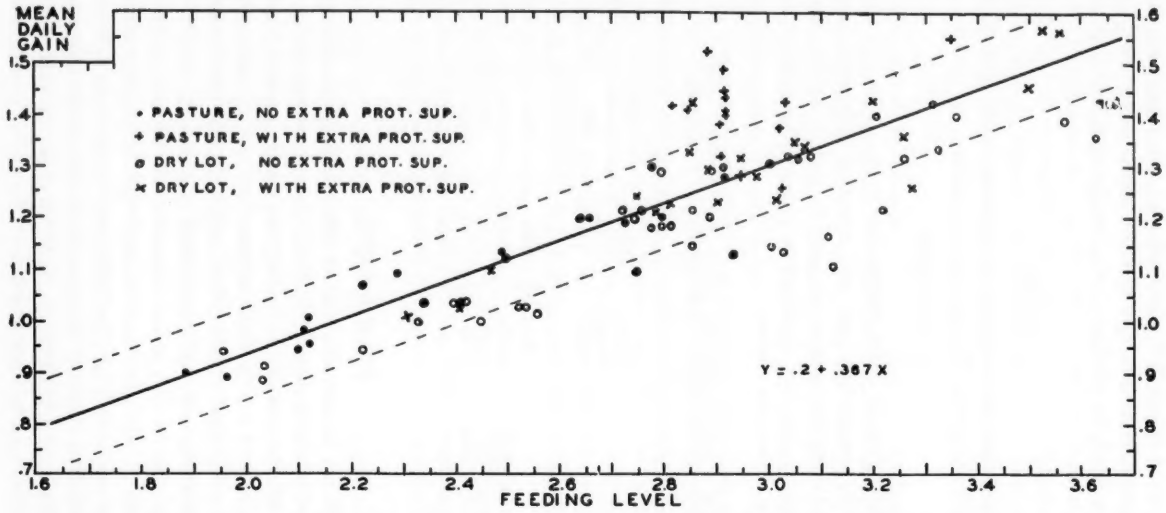

Figure 1. Effect of Feeding Level on The Daily Gain of Pigs for 4 Classes of Rations. Regression equation all groups, $Y=.20+.367\,X$. Regression equation group 1, $Y=.27+.338\,X$. Regression equation group 2, incomplete data, no feeding level below 2.85. Regression equation group 3, $Y=.24+.333\,X$. Regression equation group 4, $Y=.16+.385\,X$. Dotted lines represent standard deviation.

The mean daily gains of pigs in classes 1 and 2 were 1.10 and 1.41 pounds respectively, but the feeding levels were 2.46 and 2.96. What would have been the difference in daily gains if the two groups had been at the same feeding level? Calculations as given in table 1, made by means of equation (1), show that the pigs of class 1 did not deviate from the estimate and that those in class 2 gained .12 pound per day more than the estimate. It appears from this that the addition of protein supplement to the ration of pigs on alfalfa pasture had the effect of increasing the average daily gain by .12 pound.

The pigs in class 3 not receiving extra protein supplement made .06 pound average daily gain less than would be expected from the estimate indicating that the lack of extra protein supplement reduced their daily gains by that amount. In class 4 the deviation of estimated from expected gains was only .01 pound.

Summary

This study is based on results obtained from feeding experiments conducted with 95 groups of pigs through a period of 20 years. The period of experimentation with each group was between weaning age and a finishing weight of approximately 200 pounds.

All groups of pigs received alfalfa in some form, a grain concentrate, and skimmilk, but part of them received an additional protein supplement and others did not. They were divided into four classes: (1) Pasture with no extra protein supplement, (2) Pasture with extra protein supplement, (3) Dry lot with no extra protein supplement, and (4) Dry lot with extra protein supplement.

The pigs in class 2 made the most rapid gain and those in class 3 the least rapid gain at any given feeding level.

With all groups included, the regression equation was found to be $Y=.2+.367X$ in which Y represents daily gain and X the feeding level. The feeding level was found by dividing the average total digestible nutrients fed per day by the mean liveweight.

The regression equation may be used (1) to indicate the efficiency of any ration that has been used, and (2) as a means of estimating what the daily gain would be at any feeding level.

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SARDINE CONDENSED FISH SOLUBLES AND RYE PASTURE FOR SOWS DURING GESTATION AND LACTATION[1]

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D. E. BECKER AND W. E. CARROLL[3]
University of Illinois[4]

THE effect of the nutrition of sows during gestation upon the survival and growth rates of their pigs was described in a recent report by Fairbanks, Krider, and Carroll (1945). Data was presented showing that the fortification of certain rations with high-quality alfalfa meal during the gestation period increased the percentage of pigs weaned from 10 percent to 82 percent under drylot feeding conditions. Similar results were obtained when dried corn distillers' solubles, crystalline vitamins, or a combination of alfalfa meal and distillers' solubles was fed to supply the B_2 factors.

Purpose

The test was designed to determine: (1) the supplementary effect of 3 percent (lot 2) and 6 percent (lot 3) condensed sardine fish solubles, and rye pasture (lots 4 and 4a) when fed to sows during gestation and lactation in addition to the basal ration (lot 1) described in the next section; and (2) the residual effect during lactation of rye pasture fed during gestation (lot 4b).

Procedure

Twenty-nine spring-farrowed gilts, which had been grown on bromegrass pasture during the summer were placed on the experiment in four groups in the fall of 1944 before they were bred. These groups were fed the rations indicated above throughout gestation and lactation, except that after they had farrowed four sows of lot 4 were transferred from rye pasture to drylot, and were continued on the basal ration alone. This group is designated as lot 4b. The remaining sows (designated as lot 4a) of the original lot 4 were continued on the same ration they had received during gestation, namely, the basal ration supplemented with rye pasture. The performance of the sows at farrowing time and the survival and growth of their pigs

[1] This investigation was supported by the donation of funds and products to the University of Illinois by Central Soya Company, Inc. The high-quality alfalfa meal was kindly supplied by Ralston Purina Company, St. Louis, Missouri.

[2] Present Address, American Dry Milk Institute, Inc., Chicago, Illinois.

[3] Acknowledgement is gratefully made for the assistance of R. H. McDade, Chief Swine Herdsman, and his associates.

[4] Animal Husbandry Department, Urbana, Illinois.

during the suckling period were used as measures of the relative values of the rations.

The feeding and management practices were the same as those described by Fairbanks *et al.* (1945). The basal ration is given in table 1, together with analyses of composition and vitamin content.

TABLE 1. BASAL RATION USED IN STUDIES REPORTED

Ingredients	Pounds	Composition and vitamin content	
Ground yellow corn	67.0	Crude protein	17.0 %
Expeller soybean meal	25.0	Calcium	0.74%
Alfalfa meal (dehydrated)[1]	5.0	Phosphorus	0.49%
Minerals[2]	2.5	Manganese, p.p.m.	46.
Fortified cod-liver oil[3]	0.5	Riboflavin, mg. per lb.	2.8[4]
		Niacin, mg. per lb.	9.6
	100.0	Pantothenic acid, mg. per lb.	4.6
		Choline, mg. per lb.	177.4[4]
		Methionine	0.4 %[4]

[1] Alfalfa meal supplied and assayed by Ralston Purina Company, St. Louis, Mo.

[2] A complex mineral mixture was used. It was composed of:

Iodized salt	25.0%	Potassium carbonate	0.2 %
Steamed bone meal	29.0%	Copper sulfate	0.1 %
Ground limestone	40.0%	Manganese sulfate	0.56%
Magnesium carbonate	4.0%	Cobaltous chloride	0.10%
Ferrous sulfate	1.0%	Zinc carbonate	0.04%

[3] Guaranteed to contain 2000 I.U. of vitamin A and 400 U.S.P. units of vitamin D per gram.

[4] Kindly determined by Central Soya Co., Biological Laboratory, Decatur, Ind.

The Association of American Feed Control Officials has tentatively defined condensed fish solubles as "the product obtained by condensing the water resulting from the hydraulic extraction of oil from fish."

The average analysis of the sardine condensed fish solubles fed in this experiment was as follows: moisture 52.45 percent, ash 10.57 percent, calcium 0.14 percent, phosphorus 0.80 percent, crude protein 26.38 percent, ether extract 9.97 percent, methionine 1.16 percent, riboflavin 5.97 mg. per lb., choline 885 mg. per lb., niacin 181.6 mg. per lb., and pantothenic acid 18.6 mg. per pound.

The dehydrated alfalfa meal contained 18.0 percent crude protein and 27.9 percent crude fiber. Each pound, by assay, contained 43.6 mg. of carotene and 6.67 mg. of riboflavin.

At the start of the experiment on November 13, 1944, the $1\frac{3}{4}$ acres of fall-seeded rye pasture used by the gilts in lot 4 during gestation was a dense stand of very green common rye about 12 inches high. During lactation, an additional one-half acre of clean rye pasture was used by the six gilts and their litters in lot 4a.

Results and Discussion

Gestation

The results obtained at the end of the gestation period are presented in table 2.

An analysis of the data, using Student's "t" test, as described by Snedecor (1940) for unpaired differences showed that birth weights of the pigs in lots 2, 3 and 4 were significantly greater than the weights of the pigs in lot 1 (basal). The somewhat lighter average birth weight of the pigs in lot 3 is thought to be accounted for, in part, by the greater number of pigs farrowed

TABLE 2. RESULTS DURING GESTATION (1944–45)

Items compared	Lot numbers and treatments			
	1 Basal (drylot)	2 Basal 97% + fish solubles 3%[1] (drylot)	3 Basal 94% +fish solubles 6% (drylot)	4 Basal +1¾ acres rye pasture
Number of gilts that farrowed	6	5	6	11[2]
Av. initial wt. per gilt, lbs.	232	228	232	232
Av. daily gain to farrow, lbs.	1.56	1.55	1.60	1.36
Av. daily feed, lbs.	7.86	7.99	7.93	6.49
Av. no. pigs farrowed per litter	8.3	7.4	10.3	7.5
Av. birth wt. per pig, lbs.	2.18	2.54	2.36	2.65
Percentage of pigs farrowed:				
Strong	62	86	65	82
Medium	16	0	10	9
Weak	18	14	24	5
Dead	4	0	1	4
Immature	0	0	0	0

[1] Sardine condensed fish solubles fed on the fresh basis.
[2] An additional gilt did not conceive and was discarded.

per litter in this lot. Apparently litter size was not adversely affected by feeding the unsupplemented basal ration during gestation. Inasmuch as the gilts had been on pasture preceding this experiment, this result was not surprising.

For the reason that pigs born in large litters are less likely to be strong than those born in small litters, it is believed that the high proportion of weak pigs in lot 3 was more likely due to litter size than to the ration fed. This same explanation does not apply with equal force to lot 1. There is so much

variability in strength of pigs at birth that a great deal of importance should not be attached to differences of this magnitude.

Lactation

The lactation results are given in table 3.

(a) *The Basal Ration Was Inadequate.* Although the pigs farrowed by the sows fed the basal ration appeared normal at farrowing, the inadequacy of the basal ration became apparent during the suckling period. Based on chemi-

TABLE 3. RESULTS DURING LACTATION (1945 SPRING)

Items compared	Lot numbers and treatments				
	1 Basal (drylot)	2 Basal 97% +fish solubles 3% (drylot)	3 Basal 94% +fish solubles 6% (drylot)	4a Basal +rye pasture	4b Basal (drylot)
Number of sows	6	5	6	6	5[2]
Av. no. of pigs farrowed per litter	8.3	7.4	10.3	8.8	6.0
Av. no. of pigs weaned per sow farrowed	2.2	6.8	7.3	6.5	5.4
Av. 21 day weight per pig, lbs.	9.2	11.3	11.0	11.0	11.6
Av. 56 day weight per pig, lbs.	17.1	31.1	33.7	31.9	27.4
Av. daily ration, sow and litter, lbs.	8.1	12.1	12.4	13.3	10.8
Feed eaten per 100 lbs. of gain, lbs.[3]	550	465	410	426	486
Percentage of pigs:					
Dead at birth	4	0	2	4	3
Died 1 to 3 days	30	5	13	11	0
Died 4 to 21 days	38	3	4	11	7
Died 22 to 56 days	2	0	2	0	0
Weaned	26	92	71[1]	74	90

[1] Because of large litters, eight percent (5 pigs) of the pigs farrowed were removed and placed with other sows not on this experiment.

[2] One sow farrowed 5 pigs which were adopted by another sow that farrowed only 3 pigs.

[3] Calculated on the basis of feed consumption and gains from time gilts were started on the experiment until they weaned their litters. Includes gains of sows and their pigs, but not the gains of pigs which died.

cal analyses and vitamin assays, the content of known required nutrients in this ration should have been adequate. However, large pig losses were encountered during the first three weeks of lactation.

Gross external symptoms of a more or less typical litter of pigs from lot 1 are described below. Between 2 and 5 days of age they became listless, wob-

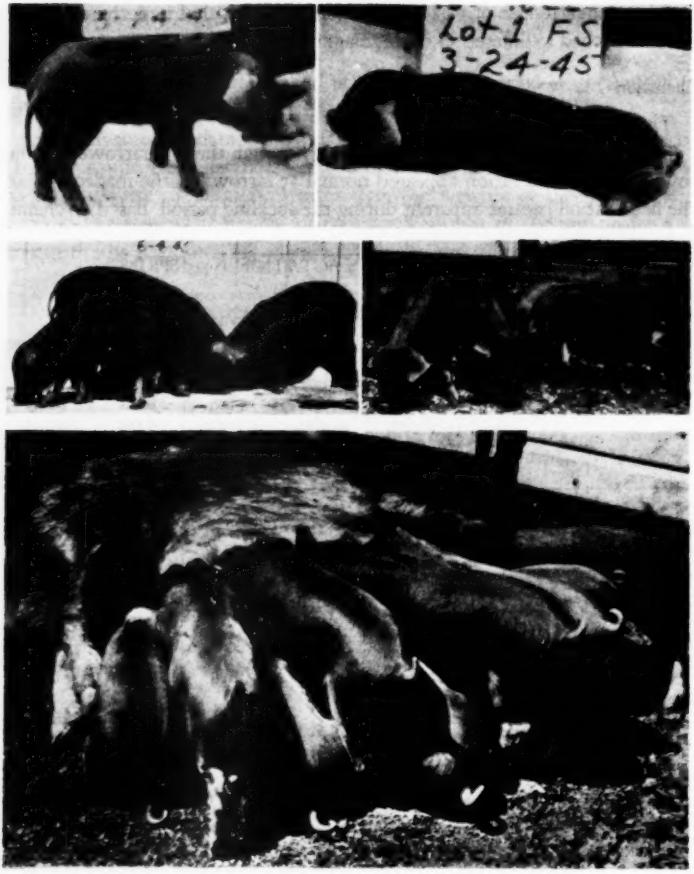

Figure 1. (Top). Deficiency symptoms observed in pigs 10 (left) and 5 (right) days after farrowing.

Figure 2. (Middle). Twelve pigs averaging 15.6 pounds each were weaned from these two basal litters. The litters were 56 (left) and 47 (right) days old at the time of photographing.

Figure 3. (Bottom). This sow and litter received 3 percent of fish solubles as a supplement to the basal ration.

bly, and weak, even though they had been strong at birth. Their haircoats did not become rough at this age. They did not recover when given sugar subcutaneously, as would be expected had they been affected with so-called

baby-pig disease (Graham *et al.*, 1941; Sampson *et al.*, 1942). The pigs laid on their bellies or sides, their front legs were extended and spraddled, their rear legs were stretched out, and many died under the electric pig brooder. Some pigs crawled off the farrowing platform and died at the edge of the farrowing pen. In figures 1 and 2 some pigs from the basal group are shown.

At eight weeks of age, the surviving pigs of this group averaged only 17 pounds. They were emaciated and very unthrifty, had rough haircoats, were listless, and had wobbly, unsteady gaits (figure 2).

Autopsy of the pigs revealed yellowish, enlarged, fatty-like livers; hypertrophied, hyperaemic kidneys; enlarged, slightly discolored hearts; normal lungs and intestines, and almost without exception, the stomachs contained milk and, in older pigs, some solid feed. In most cases the stomachs were full of milk at autopsy. Histological studies of the tissues are being made.

The sows in the basal group were good mothers, were very thrifty and appeared to give adequate amounts of milk.

(b) *Sardine Condensed Fish Solubles Effectively Supplemented the Basal Ration.* By supplementing the basal ration with either 3 or 6 percent of sardine solubles (fresh basis), growth rates to 21 and 56 days of age were significantly increased. While only 26 percent of the basal pigs survived until weaning, the addition of 3 percent and 6 percent of fish solubles to the basal ration increased the percentage of pigs weaned to 92 and 71,[5] respectively.

(c) *Supplementary Value of Rye Pasture.* During gestation, the gilts on rye pasture rooted in the snow when it covered the ground to obtain green feed. The gilts that continued on rye pasture during lactation weaned 74 percent of their pigs with a weaning weight of 32 pounds per pig. In comparison to the basal ration, weights of the pigs were significantly greater at 21 and 56 days than the weights of pigs in the basal group. Continuous feeding of the basal ration on rye pasture produced very satisfactory results.

(d) *Residual Effect.* To obtain a relative measure of the "carry-over" effect of feeding on rye pasture during pregnancy upon subsequent lactation performance in drylot, four gilts from lot 4 were used. This group was designated as lot 4b, and was self-fed the basal ration in drylot throughout the lactation period. That rye pasture did exert a significant residual effect under these conditions was amply demonstrated by the survival and growth of the pigs from these dams. Sows treated in this manner weaned 90 percent of their pigs while only 26 percent of the pigs were raised by sows fed the basal ration without supplementation during both gestation and lactation.

At 21 days of age the pigs of lot 4b were heavier than the pigs in any other

[5] Because of large litters, an additional 8 percent of the pigs farrowed were placed with other sows not on this experiment.

group by a slight margin and were about one-fourth heavier than the pigs of the basal group. That the residual effect of pasture did not continue to the end of the suckling period, however, was clear from the fact that the pigs of supplemented groups were 14 to 23 percent heavier at 56 days of age than those of lot 4b. In spite of this apparent "wearing out" of the residual effect of pasture, it brought the pigs to weaning time 60 percent heavier than pigs of the basal group.

Since deficiency symptoms appeared in the pigs nursing the sows fed the basal ration continuously in drylot before they were three weeks old, as well as later, it appears that the necessary factor (or factors) was lacking in the basal ration and that the factor (or factors) was present in all the supplements fed and was transferred through the sow's milk to the nursing pigs. In view of the fact that the amino acid content of milk protein is quite constant and is not affected by diet, it appears further that the factor (or factors) is not protein in nature.

According to present nutritional concepts, the amino acids, in excess of those used for maintenance, growth, development of the fetuses, milk production, etc., are deaminized and the non-nitrogenous residue may be used or stored as a source of energy, and are not stored in the body as amino acids for future use; whereas, certain chemical compounds such as vitamins are stored in sufficient amounts to meet the current needs of the body for several weeks or even months depending on the nutrient involved. Therefore, it seems reasonable that the residual effect of feeding rye pasture during gestation which was manifested when the basal ration was fed in drylot during lactation was probably due to a storage of vitamin-like factors in the tissues of the sow to be utilized during the suckling period, when a less adequate ration was being fed. This phase of the experiment is being repeated.

Summary

A basal ration composed of ground yellow corn, expeller soybean meal, five percent dehydrated alfalfa meal, fortified cod-liver oil, and minerals, and which contained 17 percent crude protein was nutritionally inadequate for gestation and lactation under drylot conditions. Only 26 per cent of the pigs, averaging 17.1 pounds, were weaned by sows fed this ration. Deficiency symptoms are described.

The addition of either three or six percent of sardine condensed fish solubles (fresh basis) effectively corrected the deficiency (or deficiencies) of the basal ration for gestation and lactation in drylot. Survivals of pigs so fed to weaning time were 92 and 71 percent with average weights of 31.1 and 33.7 pounds, respectively. The pigs in both groups were very growthy and thrifty. The fish solubles was apparently providing supplementary nutrients,

probably vitamin-like, which were necessary for satisfactory growth, gestation and lactation.

Fall-seeded rye pasture also proved to be an excellent source of the supplementary nutrients required to correct the inadequacies of the basal ration. Gilts receiving rye pasture weaned 74 percent of their pigs with a weaning weight of 31.9 pounds each.

The importance of adequate nutrition during gestation as a factor in promoting successful lactation and the value of rye pasture as a vitamin supplement is clearly demonstrated. The residual effect of rye pasture as a supplement to the inadequate basal ration fed during gestation, is shown by a survival of 90 percent and an average weight of 27.4 pounds for pigs from dams so fed compared with a survival of only 26 percent and an average weight of only 17.1 pounds for pigs from dams fed only the basal ration during gestation as well as during lactation. It is suggested that the residual effect manifested was probably due to a storage of a vitamin-like factor (or factors) in the tissues of the sows while on rye pasture. These reserves were then used during lactation, thus enabling the pigs to survive and perform more satisfactorily.

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THE RELATION OF CERTAIN OBJECTIVE MEASUREMENTS TO WEIGHTS OF BEEF CATTLE

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IT IS evident that there is need for a practical means of estimating the weight of beef cattle where there is no access to scales. Objective measurements have, until recently, been largely confined to growth studies. Investigations with dairy cattle, indicating significant relationships between certain measurements and weight, have resulted in the development of easily determined growth standards (Ragsdale, 1934; Davis *et al.*, 1937).

Body measurements have been used to interpret growth (Hogan, 1929; Lush *et al.*, 1930; Moulton *et al.*, 1921, Schutte, 1935) and production (Black *et al.*, 1938; Knapp, 1939; Lush, 1928, 1932) factors in beef cattle. Measurements have also been used to describe size inheritance in cattle (Gregory, 1933) and types and breeds (Ashton, 1930; Hultz, 1927; Hultz and Wheeler, 1927; Swett *et al.*, 1928) of beef cattle.

There have only been a limited number of investigations on the use of body measurements for the estimation of weight of beef cattle (Knapp, 1937; Plokhinsky and Masterova, 1935; Soares Veiga, 1939).

The object of the analyses reported in this paper was to study the interrelationships of various body measurements for the purpose of establishing a criterion of measurement reliably associated with weight in fat cattle.

Source of Data

The cattle from which the data used in these studies were obtained were 145 4-H Aberdeen-Angus and Hereford yearling steers exhibited at the 1941, 1942, and 1943 New York State Fairs. Within breeds, they were essentially of the same breeding and were raised under very similar conditions. These good to choice baby-beef steers were full fed in dry lot for 240 to 300 days and weighed 640 to 1,150 pounds when the various measurements were taken.

Heart girth measurements and actual weights were obtained in all three years. In addition, in 1942 and 1943, height at withers, patella or round, and body length were also measured and recorded. The procedures for taking these measurements were as follows: After the animal was weighed on a set of platform scales, it was placed squarely on all four feet with its head in the normal upright position. A cloth tape, one-half inch wide and graduated in

[1] The authors are indebted to Professor H. A. Willman, Department of Animal Husbandry, who made it possible to obtain these measurements and weights.

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inches, was used to take the heart girth, patella or round, and body length measurements. The heart girth measurement was obtained by placing the tape around the animal at the point of smallest circumference just behind the forelegs. It was pulled snugly about the animal, tight enough to keep the hair down but not tight enough to indent the flesh. The height at withers was determined with a metal caliper graduated in inches. The patella or round measurement was taken with the cloth tape, measuring from the anterior external point of one patella, the first fixed point, posteriorly and horizontally about the muscles of the round to a corresponding point on the opposite patella, the second fixed point.

All of these measurements were taken five times, the animal being moved between each measurement to a "normal" position. An average was taken as a representative figure. Body length was measured using the cloth tape, with the animal in a "normal" position, as the length from the pin bone to the prominence on the shoulder, located about one inch posterior to the point of the shoulder. Two body length measurements were taken and averaged to obtain a representative figure.

In addition, in 1941 data were obtained on the heart girth measurements and weights of 27 Aberdeen-Angus heifers and cows of the University herd ranging in age from two to twelve years.

Analysis of Data

For purposes of analysis, the data were separated according to breeds and further grouped according to the actual weights of the cattle. Within breeds, all of the steers weighing 1,000 pounds or more were called "heavy," those ranging from 900 to 999 pounds in weight were termed "medium," while the steers weighing 899 pounds or less were termed "light."

The method suggested by Johnson (1940) for determining weight in cattle: heart girth $\times$ heart girth $\times$ body length $\div$ 300 = weight in pounds, was used to calculate the Minnesota formula.

A study of the data indicated that the group means or adjusted averages were proportional to their standard deviations or variance from a straight line. Because of this relationship, the data were studied by transforming the measurements and weights to logarithms.

The correlation coefficients and the regression lines were calculated and their significance was interpreted according to Snedecor (1940).

Results

Correlation coefficients showing the relationship between the heart girth measurement and body weight of 145 Aberdeen-Angus and Hereford yearling steers, and 27 Aberdeen-Angus heifers and cows appear in table 1. The

coefficient for the 45 Hereford steers, 0.91, was highly significant, as was that for the 100 Aberdeen-Angus steers, 0.89, for all 145 steers, 0.88, and for the heifers and cows, 0.93.

TABLE 1. CORRELATION COEFFICIENTS SHOWING RELATIONSHIP BETWEEN HEART GIRTH MEASUREMENTS AND WEIGHTS OF 145 ABERDEEN-ANGUS AND HEREFORD STEERS AND 27 ABERDEEN-ANGUS HEIFERS AND COWS

Breed and group	Number	Range in weight	Range in heart girth	Correlation coefficient
		pounds	*inches*	
Aberdeen-Angus				
Heavy	32	1000–1120	73.5–79.2	0.32
Medium	39	900–995	71.5–77.0	0.60**
Light	29	640–885	62.0–76.0	0.87**
Total	100	640–1120	62.0–79.2	0.89**
Hereford				
Heavy	14	1000–1150	75.0–80.0	0.56*
Medium	13	903–985	68.8–76.0	0.57
Light	18	695–890	65.0–71.5	0.70**
Total	45	695–1150	65.0–80.0	0.91**
All Steers				
Heavy	46	1000–1150	73.5–80.0	0.35*
Medium	52	900–995	68.8–77.0	0.54**
Light	47	640–890	62.0–76.0	0.76**
Total	145	640–1150	62.0–80.0	0.88**
Aberdeen-Angus Heifers and Cows	27	845–1460	67.8–79.8	0.93**

* Significant at the 5 percent level of probability.
** Significant at the 1 percent level of probability.

This analysis indicated a definite trend toward increased magnitude and significance of this relationship for the "light" steers as compared with the "heavy" steers, and therefore a greater accuracy in the use of heart girth measurements to estimate the body weight of lighter or thinner cattle. In this regard, the correlation coefficient between heart girth and weight was smaller for the cows than for the heifers.

Calculation of the regression of the logarithms of actual live weight on the logarithms of heart girth measurements indicated that a straight line relationship existed. The regression equations, in logarithms, for estimating weight (E) of cattle, based on the data obtained from the steers, heifers, and

cows, appear in table 2. Using these equations, the estimated weights for the various heart girth measurements were calculated and appear in table 3.

TABLE 2. REGRESSION EQUATIONS, IN LOGARITHMS, FOR ESTIMATING THE WEIGHT OF CATTLE

Breed and sex	Number	Regression equation
Aberdeen-Angus steers	100	$E=2.37082X-1.44261$
Hereford steers	45	$E=2.39859X-1.48411$
All steers	145	$E=2.30016X-1.30715$
Aberdeen-Angus heifers and cows	27	$E=2.94745X-2.46896$

E equals calculated logarithm of weight.
X equals logarithm of heart girth measurement.

TABLE 3. ESTIMATED WEIGHTS FOR VARIOUS HEART GIRTH MEASUREMENTS OF GOOD-TO-CHOICE ABERDEEN-ANGUS AND HEREFORD YEARLING STEERS, AND FOR ABERDEEN-ANGUS HEIFERS AND COWS

Heart girth	Weight			
	Aberdeen-Angus steers	Hereford steers	All steers	Aberdeen-Angus heifers and cows
inches	*pounds*	*pounds*	*pounds*	*pounds*
60	593	604	607	592
61	617	628	630	621
62	641	653	654	652
63	666	679	679	683
64	691	705	704	716
65	717	732	729	749
66	743	759	755	784
67	770	787	782	819
68	798	815	809	856
69	826	844	837	893
70	855	874	865	932
71	884	904	893	972
72	914	935	923	1013
73	944	967	952	1055
74	975	999	983	1098
75	1007	1031	1013	1142
76	1039	1065	1045	1187
77	1071	1099	1077	1234
78	1105	1133	1109	1282
79	1139	1168	1142	1331
80	1173	1204	1176	1381
81	1208	1240	1210	1433
82	1244	1277	1244	1486
83	1280	1315	1280	1540
84	1317	1353	1315	1595
85	1354	1392	1351	1652

The regression lines for the Aberdeen-Angus steers and for the Hereford steers were parallel (figure 1). These lines showed that the Aberdeen-Angus

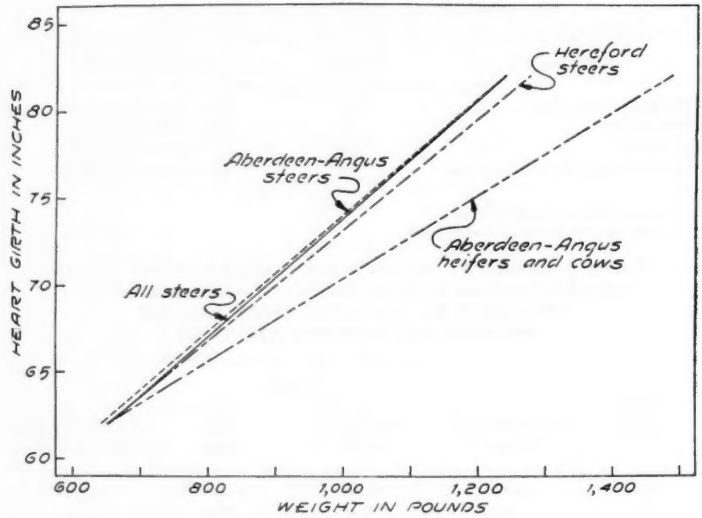

Figure 1. Regression lines of heart girth measurements on weights of beef cattle.

steers were lighter than the Hereford steers in relation to their heart girth measurements. The regression line for the heifers and cows indicated that they were heavier than were the steers in relation to their heart girth measurements, especially at the larger tape measurements.

TABLE 4. CORRELATION COEFFICIENTS SHOWING INTERRELATIONSHIPS BETWEEN VARIOUS MEASUREMENTS OF 36 ABERDEEN-ANGUS STEERS WEIGHING 640 TO 1,120 POUNDS

Measurement	Height at withers	Patella	Body length	Minnesota formula	Weight
	inches	*inches*	*inches*		*pounds*
Heart girth, inches	0.71**	0.32	0.66**	0.97**	0.95**
Height at withers		0.21	0.75**	0.78**	0.81**
Patella			0.27	0.33	0.34
Body length				0.83**	0.80**
Minnesota formula					0.98**

Correlation coefficients showing the interrelationship between the various measurements of 36 Aberdeen-Angus steers, which weighed 640 to 1,120 pounds, were calculated. As may be seen from table 4, there was a highly significant correlation between the following: heart girth and height at withers, heart girth and body length, heart girth and weight, height at withers and body length, height at withers and weight, and body length and weight. As would be expected, the Minnesota formula was very highly correlated with the measurements upon which its calculation is based, namely, heart girth and body length. The highest correlation with weight was between the Minnesota formula and weight, closely followed by that between heart girth and weight.

Correlation coefficients showing the interrelationships between the same measurements of 30 Hereford steers weighing 695 to 1,117 pounds, as shown in table 5, were highly significant for all combinations except that between height at withers and patella, which was significant. The highest correlation with weight was between the Minnesota formula and weight, and was again closely followed by that between heart girth and weight.

TABLE 5. CORRELATION COEFFICIENTS SHOWING INTERRELATIONSHIPS BETWEEN VARIOUS MEASUREMENTS OF 30 HEREFORD STEERS WEIGHING 695 TO 1,117 POUNDS

Measurement	Height at withers	Patella	Body length	Minnesota formula	Weight
	inches	*inches*	*inches*		*pounds*
Heart girth, inches	0.52**	0.55**	0.66**	0.96**	0.89**
Height at withers		0.38*	0.48**	0.55**	0.61**
Patella			0.56**	0.60**	0.59**
Body length				0.84**	0.83**
Minnesota formula					0.94**

In general, when the data was separated into "light," "medium," and "heavy" steers, the correlation coefficients between the various measurements and weight decreased in that direction, indicating a greater accuracy of heart girth measurements and the Minnesota formula in predicting the weight of "light" steers as compared with "heavy" cattle.

A calculation of the interrelationships between these measurements for all of the Aberdeen-Angus and Hereford steers (table 6) showed that all of the coefficients were highly significant, with the exception of that between height at withers and patella, which was significant. The highest correlation with weight was the Minnesota formula, closely followed by that between heart girth and weight.

TABLE 6. CORRELATION COEFFICIENTS SHOWING INTERRELATIONSHIPS BETWEEN VARIOUS MEASUREMENTS OF 66 ABERDEEN-ANGUS AND HEREFORD STEERS WEIGHING 640 TO 1,120 POUNDS

Measurement	Height at withers	Patella	Body length	Minnesota formula	Weight
	inches	*inches*	*inches*		*pounds*
Heart girth, inches	0.63**	0.37**	0.64**	0.97**	0.93**
Height at withers		0.28*	0.63**	0.69**	0.73**
Patella			0.38**	0.40**	0.42**
Body length				0.82**	0.80**
Minnesota formula					0.97**

Summary

A study was made of the relationship between the heart girth measurement and the body weight of 100 Aberdeen-Angus and 45 Hereford good-to-choice fat yearling steers ranging in weight from 640 to 1,150 pounds. Also, data were obtained on height at withers, patella or round, and body length for 36 of the Aberdeen-Angus steers and for 30 of the Hereford steers. Heart girth measurements and body weights were also obtained on 27 Aberdeen-Angus heifers and cows of the University herd, ranging in age from two to twelve years.

The coefficients of correlation between heart girth and body weight were 0.91 for the Hereford steers, 0.89 for the Aberdeen-Angus steers, 0.88 for all steers, and 0.93 for the heifers and cows, all highly significant statistically. These coefficients were of a higher magnitude for the lighter steers as compared with the heavier steers, indicating a greater accuracy in predicting the weight of the former. The correlation coefficient for the cows was smaller than that for the heifers, each being smaller than the correlation coefficients for the steers.

A calculation of the regression of the logarithms of actual live weight on the logarithms of heart girth measurements, indicating a straight line relationship, showed that the Aberdeen-Angus steers were lighter than the Hereford steers in relation to their heart girth measurements. The regression line for the heifers and cows indicated that they were heavier than the steers in relation to their heart girth measurements, especially at the larger tape measurements.

Regression equations, in logarithms, for predicting weight from heart girth measurements are presented.

Calculation of the interrelationships between heart girth, height at withers, patella or round, body length, the Minnesota formula (heart girth × heart girth × body length ÷ 300), and body weight for all of the steers

showed that the correlation coefficients were highly significant for every combination except for that between height at withers and patella, which was significant. There was a trend towards greater significance in these relationships for the lighter steers as compared with the heavier steers. The most significant single measure for estimating weight was the heart girth measurement, which was only slightly less significant than the more detailed estimation obtained by using the Minnesota formula.

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METHODS FOR IDENTIFYING FEEDS AND MEASURING THEIR RATE OF PASSAGE THROUGH THE RUMEN OF CATTLE

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INVESTIGATIONS at this station, Burroughs *et al.* (1945), have indicated that corn cobs have a substantial feeding value when incorporated in beef-cattle rations. Utilization of the "woody" portion of cobs and other roughages probably centers principally around the activities occurring within the rumen. The length of time a feed remains in the rumen would thus appear to influence its eventual utilization.

The purpose of this paper is to present methods of identifying different feeds within the rumen ingesta and to determine their rate of passage through this segment of the digestive tract.

Comparison of Methods

Two methods for identifying feeds within the rumen were used. The first method involved a mathematical equating of nutrients occurring in the feeds fed with the nutrients found in the mixture of feeds contained in the rumen ingesta. The second method of feed identification consisted of physical separation of recognizable components of the ration in rumen material.

The rate of passage of individual feeds through the rumen was computed from differences in the determined amount of each feed in the rumen every 4 hours throughout a 24-hour period.

A rumen fistula was established in each of two short-yearling Hereford steers weighing about 600 pounds each. The fistula opening was closed with a pneumatic rubber plug at all times except on days that rumen samples were collected. At this time a metal-rubber-gasket plug was employed which permitted no leakage of ingesta material. This plug proved very suitable for use at short intervals of a few days; however, the looser fitting pneumatic rubber plug was more suitable for longer periods.

Both steers were fed and watered individually and were confined in stanchions the greater part of the time. During good weather the animals had access to a small outside vegetation-free paddock a few hours each day, except on those days rumen samplings were made and also on the preceding 2 days.

The rations used in this study consisted of corn with and without cobs,

[1] Resigned February, 1944.

hay, and protein supplement. Other rations may be used depending upon the purpose of the investigation.

Each steer was placed on a given ration at least 3 weeks prior to the 24-hour sampling period. Samples of rumeno-reticular contents were collected at 8 A.M. and the process was repeated at 4-hour intervals throughout the 24-hour period. The 8 A.M. sample was obtained just before the morning feed by removing the total rumeno-reticular content. This was weighed, thoroughly mixed, and a quart of ingesta set aside for analysis. An amount of corn, hay, and protein supplement in the proportions contained in the steer's ration was added to the ingesta based upon the estimated amount of dry feed removed in the wet ingesta saved for chemical analysis. The ingesta including this small increment of feed, was then returned to the animal. The entire sampling process required approximately 15 minutes.

The steer was then fed and watered, which usually required from 30 to 60 minutes. In a few cases the entire ration was not consumed in 60 minutes; this necessitated the adding of the refused feed to the ingesta through the fistula opening. Water consumption during the sampling period was regulated to the average water intake of the steer during the preceding 3 weeks or by adding water through the fistula opening in case it was not readily taken.

The evening feed and water were given immediately following the taking of the 4 P.M. sample. The steers were under constant observation during the collection period to insure against any accidental rumen leakage or unusual happenings which might seriously influence the measurements.

The wet ingesta samples were weighed and then dried 7 to 10 days, or until they reached a constant weight at 50°C. This slow drying procedure perhaps caused some loss of ingesta nutrients. The samples were then allowed to gain moisture from the air for a period of 24 to 48 hours, weighed and ground for analysis. Crude fiber, protein, ether extracts, and ash were determined according to the official methods of the A.O.A.C. Dry matter was obtained by subjecting 2-gram samples to a temperature of 105°C. for 5 hours.

The mathematical method employed in estimating the amounts of different feeds in the rumen was based upon the nutrient composition of the feeds consumed and the total weights of the various nutrients found in the rumen at a given time. Three nutrients were selected to evaluate mathematically each feed present in the rumen ingesta. The nutrients selected were protein, nitrogen-free-extract, and crude fiber. The reasons for selecting these three nutrients were two-fold: First, they made up about 90 percent of the nutrients found in the feeds, second, these three nutrients are found in dis-

tinctly varying ratios in each of the three feeds—protein supplement, hay, and corn.

Three algebraic equations were set up simultaneously, each consisting of the same three unknowns which permitted their solution by subtraction or addition of one equation to another. The first equation pertained to protein in the rumen ingesta, the second to nitrogen-free-extract, and the third was related to crude fiber in the ingesta. Three unknowns in each equation were the amounts of each of the feeds fed; namely, protein supplement, hay, and corn.

The method may be illustrated as follows:

Let: A = pounds of protein supplement in rumen ingesta.

B = pounds of hay in rumen ingesta.

C = pounds of corn in rumen ingesta.

First equation based upon protein content of rumen ingesta:

$$\frac{A \times (\%\text{ protein in supp.})}{100} + \frac{B \times (\%\text{ protein in hay})}{100} + \frac{C \times (\%\text{ protein in corn})}{100} = \text{pounds protein in ingesta.}$$

Second equation based upon nitrogen-free-extract content of rumen ingesta:

$$\frac{A \times (\%\text{ N-F-E in supp.})}{100} + \frac{B \times (\%\text{ N-F-E in hay})}{100} + \frac{C \times (\%\text{ N-F-E in corn})}{100} = \text{pounds N-F-E in ingesta.}$$

Third equation based upon crude fiber content of rumen ingesta:

$$\frac{A \times (\%\text{ fiber in supp.})}{100} + \frac{B \times (\%\text{ fiber in hay})}{100} + \frac{C \times (\%\text{ fiber in corn})}{100} = \text{pounds fiber in ingesta.}$$

Substituting the experimentally determined nutrient values of feeds and ingesta:

Equation 1. $$\frac{A(40)}{100} + \frac{B(20)}{100} + \frac{C(10)}{100} = 1.5$$

Equation 2. $$\frac{A(30)}{100} + \frac{B(40)}{100} + \frac{C(70)}{100} = 2.5$$

Equation 3. $$\frac{A(10)}{100} + \frac{B(30)}{100} + \frac{C(5)}{100} = 1.5$$

Simplifying:

Equation 1. $.40A + .20B + .10C = 1.5$

Equation 2. $.30A + .40B + .70C = 2.5$

Equation 3. $.10A + .30B + .05C = 1.5$

Multiplying equation 1 by (3), equation 2 by (4), and equation 3 by (12).

Equation 1.′ $1.20A + .60B + .30C = 4.5$

Equation 2.′ $1.20A + 1.60B + 2.80C = 10.0$

Equation 3.′ $1.20A + 3.60B + .60C = 18.0$

Subtracting equation 2′ from equation 1′ and subtracting equation 3′ from equation 2′.

Equation 4. $-1.00B - 2.50C = -5.5$

Equation 5. $-2.00B - 2.20C = -8.0$

Multiply equation 4 by (2).

Equation 4.′ $-2.00B - 5.00C = -11.0$

Equation 5. $-2.00B - 2.20C = -8.0$

Subtracting equation 5 from equation 4′.

$-2.80C = -3.0$ $C = 1.07$ pounds corn.

Substituting the value of C in equation 5.

$-2.00B - 2.20(1.07) = -8.0$ $B = 2.82$ pounds hay.

Substituting the values of B and C in equation 1.

$.40A + .20(2.82) + .10(1.07) = 1.5$ $A = 2.08$ pounds protein supplement.

Physical separation of the corn grain from the rumen ingesta was made on a limited number of samples. Two methods were used in this work, both of which appeared to have merit. The first made use of a small-grain fanning mill and the second was a water-floatation method. Approximately one

quart of wet ingesta was removed from the steer at the time the sample for chemical analysis was withdrawn. The sample was dried to constant weight in a low-temperature forced-air oven. It was then separated by means of screens to determine the Modulus of Fineness (not reported). The dry ma-

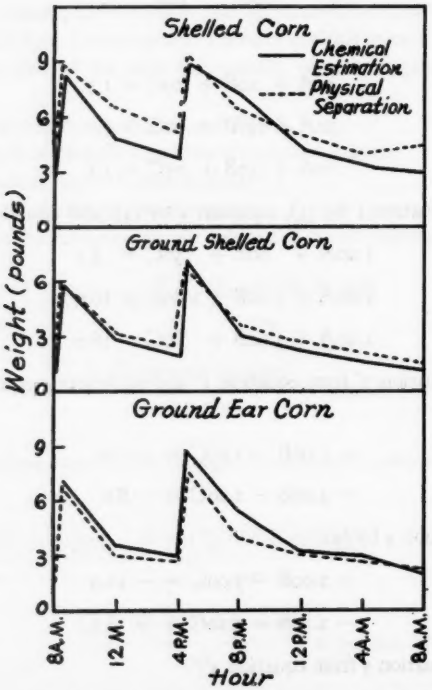

Figure 1. Chemical estimation of corn in rumen compared with physical separation. Each point is based on an average of four determinations. Animals were fed and watered at 8:30 A.M. and 4:30 P.M.

terial was then run through a fanning mill or into the water-floatation system.

The fanning mill was of the type commonly used in cleaning small quantities of seeds. The corn separation was made partly with the aid of different sized shaker screens in the mill and partly by the distance the materials were carried by the blast of air from the fan. The grain portion was run through the mill a number of times until the appearance closely resembled that of the original ground corn.

The floatation method consisted of placing the dry material into a tall glass container and directing water at a desired rate through a hose which reached down into the flask. The water entering the container stirred the entire contents, the lighter hay and cob particles coming to the top and overflowing the jar, whereas the heavier corn particles remained at a lower strata in the container. Following this process the grain was allowed to settle, decanted, dried, and weighed.

Chemical Estimation vs. Physical Separation of Rumen Corn

The amount of corn present in the rumen when determined by chemical estimation as compared with physical separation methods is presented in figure 1.

Physical separation of the rumen corn fed in the shelled-corn ration was accomplished with the use of a small fanning mill; whereas the floatation method of separation was used for the rumen grain when the ground-shelled-corn and ground-ear-corn rations were fed. Both methods of physical separation produced corn values approximating those obtained with the chemical method. The general agreement of physical separation methods with the mathematical estimations based on rumen-content analysis lends support to the general validity of all determinations.

A further consideration of these methods and their application will be given in a later report of work concerning the feeding value of different forms of corn for cattle.

Discussion

The question of the influence of a rumen fistula upon normal function of the organ cannot be answered definitely. It is, however, believed to be inconsequential in most respects, provided the opening is properly closed with a well-fitted plug which prevents leakage of ingesta and at the same time is not irritating to the surrounding tissue of the animal. A comparison of the gains made in liveweight and the general appearance of the fistula cattle used in this experiment with those of cattle without fistulae which were used in a parallel experiment give support to this assumption.

The repeated removal and return of the rumen contents at 4-hour intervals throughout a 24-hour period did not appear to influence the rate of passage of materials through this compartment of the digestive tract. This was exemplified by the similarity in the amounts of water and dry matter found at 8:00 A.M. when examinations began with the amounts of liquid and dry matter found the following morning at 8:00 A.M. after examinations had been in progress for 24 hours.

The replacement of the small ingesta sample saved for analysis with an

estimated equivalent amount of ration and water is somewhat in error. This is due to errors in estimating the amount of dry matter in the wet sample and the qualitative differences which exist between a mixture of feed and water as compared with that of ingesta material. The errors involved in this procedure are, however, substantially less (1 percent total ingesta per day) than those encountered when no material is added to compensate for the sample withdrawn for analysis (about 5 percent of total ingesta per day would be removed in 6 samples).

The accuracy of the estimations made on the amounts of feeds contained in the rumen, based upon mathematical treatment of chemical data, cannot be regarded beyond that of approximations. The similarity between the values obtained for corn based upon physical separation methods and the estimations mathematically arrived at is indicative that the latter method is, in the main, approximately correct. Nevertheless, the absoluteness of either method is subject to a number of factors, such as the leaching from the rumen of soluable or fine materials, Hale *et al.* (1940), and the digestion of nutrients in this segment of the digestive tract.

Summary

Methods were presented for identifying individual feeds within the rumen of cattle while feeding a mixed ration containing corn, hay, and protein supplement. A chemical method of identification was based upon mathematical treatment of the principal nutrients contained in the feeds fed and the nutrients present in the rumen ingesta. This method was checked, in part, by physically separating out the corn contained in representative samples of rumen contents. The general agreement in results obtained by the two methods was suggestive of their over-all accuracy.

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EFFECT OF TEMPERATURE AND LENGTH OF STORAGE ON ENSILAGE MADE FROM COOKED WHITE POTATOES

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THE unusually large crop of early potatoes grown during the spring of 1944 prompted the carrying out of a program through governmental agencies to utilize the surplus for livestock feeding purposes. A survey of the literature showed that considerable work had been done in Europe on the ensiling of cooked or steamed potatotes (Ruschmann and Gräf, 1931, 1931a; Waechter, 1934; Godden, 1943). Such potato ensilage was reported to keep well and to be very satisfactory for the feeding of livestock, particularly swine (Lüthge, 1931; Wallace and Thompson, 1931; Richter and Ferber, 1932; Richter and Brüggemann, 1934; Williams, 1939; Scharrer and Schreiber, 1942).

Various details of the process appeared to require further study, however, to determine the best method of adaptation to American conditions. A point of special interest was the effect of temperature of storage under conditions found in Florida or the Carolinas as contrasted with New York or New England or with Great Britain, for example. Furthermore, information was lacking on the type of fermentation set up in a cooked product by the fermenting organisms not destroyed by the cooking treatment and on the losses in nutrients during fermentation.

Materials and Methods

The present study was undertaken at the Agricultural Research Center, Beltsville, Maryland, to determine the effect of temperature on the fermentation of ensilage made from cooked potatoes and to study the chemical changes during the fermentation process and the period of storage.

Experimental silos were set up under the following conditions: (1) at a high temperature approximating 85°F., (2) at a medium temperature of 63°F., (3) at a low temperature of 35°F. and (4) with two miniature trench silos sunk below ground level. In addition, two stone jars and two Pyrex cylinders were used as silos for each of the first three conditions. One jar and one cylinder were covered the day they were filled and the others were covered after the third day. Three half-gallon Mason jar silos were also set up as follows: one fitted with a carbon dioxide absorption train at room temperature, one with a water trap at 99°F. and one with a cloth covering at 99°F. A sample was removed from the cooker and frozen immediately for use as a control sample. The trench silos were constructed of wood and were of dimensions

proportionate to those described in the literature for use in ensiling of potatoes. They were placed in the ground to a depth that permitted the covers to be placed just below the ground level and then covered with dirt to a depth of 10 to 12 inches. Each held approximately 600 pounds of cooked potatoes.

The potatoes were sorted and the rotten ones removed before cooking. They were cooked with live steam in a steel drum until they mashed easily. The steam was admitted at the center and at the bottom of the drum, which was provided with drainage holes to remove the condensate. Two hundred pounds of potatotes were cooked at one time in this manner. The silos were filled with the hot potatoes as soon as possible after cooking, and the potatoes were thoroughly tamped to remove all air pockets.

Daily maximum and minimum temperatures were recorded, for the first six weeks, for the silos serving for conditions 1 and 2. The mean temperature for condition 1 was 85°F., the maximum was 93°, the mean maximum was 88°, the minimum was 74° and the mean minimum was 82°. The mean for condition 2 was 62.5°F., the maximum was 67°, the mean maximum was 63°, the minimum was 60° and the mean minimum was 62°. The maximum for condition 3 was 44°F. and the minimum was 32° during the same period. The fermentation period for condition 4 ran from early June to late July 1944. Temperature records for the locality show that the average of the mean temperatures for these two months was 77°F., the maximum was 97° and the minimum was 50°, the mean maximum was 88° and the mean minimum was 67°.

Chemical analyses were made at intervals during the first six weeks. At the end of this period and after a year, samples were taken from all the silos kept in the laboratory and dried in a vacuum oven at 212°F. The dried material was ground through a burr mill and thoroughly mixed. Ash, crude protein, crude fiber and ether extract determinations were made on these samples. At the same time total solids, pH, starch and reducing sugar (expressed as dextrose) determinations were made on samples of the wet material and at the other intervals as listed in table 1. The wet material was prepared for analysis by running the sample through a food chopper and then mixing the sample thoroughly by hand. The analyses were made according to the published methods of the Association of Official Agricultural Chemists with modifications suited to the material under study.

After a fermentation period of six weeks the ensilage from the trench silos was fed to swine at the rate of four parts of ensilage to one part of grain mixture consisting of corn, protein supplement mixture and mineral mixture. Six pigs, averaging 53 pounds at the beginning of the test, were fed the above ration for a period of 15 days. Each pig consumed approximately 7 pounds of potato ensilage per day.

Results

The results of the chemical analyses are given in table 1. As indicated by the pH and starch values especially, temperature had a decided influence on the rate of fermentation and on the final composition of the ensilage. Under

TABLE 1. COMPOSITION OF POTATO ENSILAGE AFTER DIFFERENT FERMENTATION AND STORAGE PERIODS EXPRESSED ON THE BASIS OF ORIGINAL WET SILAGE

Sample	Dry matter	pH	Starch	Reducing sugar	Other organic matter	Ash	Crude protein	Crude fiber	Ether extract
	per cent		*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Original cooked potatoes	22.9	5.7	16.0	0.2					
Control sample, frozen for 6 weeks	22.9		15.7	0.2	3.2	1.2	1.9	0.6	0.08
Stored at low temperature:									
6 weeks	21.4	6.6	15.0	0*	2.7	1.1	2.0	0.5	0.08
14 weeks	22.3	5.2	15.2	0					
24 weeks	20.0	7.0	14.1	0					
1 year	19.8	5.2	12.0	0	4.1	1.0	2.1	0.5	0.06
Stored at medium temperature:									
3 weeks	20.7	5.4	13.0	0.2					
6 weeks	19.2	4.7	9.0	0.5	5.7	1.1	2.2	0.6	0.05
14 weeks	17.3	3.7	7.1	1.4					
24 weeks	18.2	3.9	6.8	2.2					
1 year	17.6	4.0	6.6	2.7	4.4	1.0	2.2	0.6	0.09
Stored at high temperature:									
2 weeks	17.5	4.2	4.1	2.8					
6 weeks	16.8	3.4	3.6	2.0	7.4	1.2	1.9	0.6	0.06
14 weeks	16.9	3.7	3.8	2.4					
24 weeks	16.3	3.8	4.2	2.0					
1 year	13.9	4.0	3.9	1.8	5.0	1.0	1.6	0.5	0.07
Stored in trench silo for 6 weeks	18.1	3.9	4.6	2.1	7.4	1.1	2.1	0.7	0.09

* No reducing sugar detected by method used.

the high temperature (85°F.) condition most of the fermentation took place during the first 2 weeks, while under the medium temperature (63°F.) fermentation changes occurred up to 6 months, and under the low tem-

perature (35°F.) no noticeable fermentation took place during a period of 1 year. The loss of nutrients was significantly greater at high than at medium temperature.

The samples stored at high temperature and at medium temperature had a desirable ensilage-like odor, although the odor of butyric acid was somewhat pronounced, while the odor of the sample stored at low temperature resembled that of rotten potatoes.

The formation of mold was related to the rate of fermentation. No mold was formed in the ensilage kept at high temperature, only a small amount in that stored in the trench silos, while the top layer of the material in the silos kept at 63°F. was covered with mold and several types of mold were formed on the potatoes stored at 35°.

In all the silos, the ensilage darkened whenever it was exposed to the air. No darkening occurred in silos with air traps.

No difference was observed in the pairs of silos which were set up to study the effect of immediate or delayed covering of the cooked potatoes, indicating that heat-resistant organisms were responsible for the fermentation.

Considerable gas was given off by the silos kept at approximately 85°F. and some gas by the 63° silos. Carbon dioxide was evolved in large volume by the silo with the absorption train although no quantitative determination of the gas evolution was obtained. In this silo, however, the ensilage lost 10.58 percent in weight in one month.

Ethyl and *N*-butyl alcohol were isolated from a sample of ensilage stored at room temperature, the quantities recovered being 13 ml. of *N*-butyl and 24 ml. of ethyl alcohol from 15.25 pounds of ensilage. The alcohols were identified by converting them into suitable derivatives.

A study of the pH change occurring within the first few days was also made. Freshly cooked potatoes were mashed and methyl red indicator was mixed in the lot. The mixture was divided between two glass-stoppered bottles, one left at high temperature and one placed in a refrigerator. The initial color of both bottles was pink, corresponding to a pH of 5.7. The bottle at room temperature was orange on the second day, yellow on the third day, denoting a pH of at least 6.2, while the color was red on the fourth day, denoting a pH of 4.2 or lower. The color of the sample in the refrigerator was light orange after 2 weeks. This shows that the pH becomes greater before beginning the downward trend, which is in line with the pH results on the 35° sample. The initial increase in pH is probably due to ammonia liberated in the early decomposition of protein.

There was a considerable loss of nutrients in the high temperature ensilages; at the end of one year the losses of dry matter and of the starch and

reducing sugar combined (calculated on the dry basis) were as follows: for low temperature storage, 13.5 and 14.6 percent, for medium temperature storage 23.1 and 25.8 per cent and for high temperature storage 39.3 and 56.9 percent respectively.

The losses at the end of six weeks for the ensilage stored in trenches were for dry matter, 20.93 per cent, and for carbohydrates, 48.37 percent.

During the course of this work it was difficult to obtain good sampling of the ensilage at the different periods, since it was not possible to mix the entire contents of a silo or to take cores without spoiling the material needed for later determinations. The samples were therefore taken off in layers and consequently small changes in composition between periods may be due in part to sampling procedure.

The pigs on the feeding test consumed the ensilage very readily and gained at the rate of 1.6 pounds per day, which was considered to be exceptionally good for the weight of pigs used. The amount of feed consumed per hundred pounds of gain was 423.97 pounds of potato ensilage, 73.97 pounds of corn, 30.14 pounds of protein mixture and 1.37 pounds of minerals.

Conclusions

The results of this study confirm reports that cooked potatoes can be ensiled and that the ensilage may be stored for at least one year, that the losses of nutrients are large during the fermentation period, that the temperature during the ensiling period has a decided influence on the rate and type of fermentation and hence on the final product, that the ensilage is very palatable and that it has good feeding value, when fed in a balanced diet to swine. Considering the large loss of nutrients at the higher temperatures, it would seem that a temperature of about 60°F. during the fermentation period is the most suitable for the production of potato ensilage.

Although the apparent losses of nutrients were small in the samples stored at low temperatures, these losses were due to putrefaction and not to fermentation. Samples stored at this temperature were considered to be worthless for feeding purposes and were therefore a total loss.

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A 72 PERCENT H_2SO_4 METHOD FOR THE DETERMINATION OF LIGNIN AND ITS USE IN ANIMAL NUTRITION STUDIES

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THE analyses commonly made on feedstuffs are: moisture, ether extract, crude protein obtained by multiplying nitrogen by 6.25, ash, crude fiber, and nitrogen-free extract, the latter being determined by difference. For the most part, it is on these analyses that attempts to evaluate the nutritional quality of feeds are based and with reference to which the digestibility of feeds is determined. Crampton and Maynard (1938) reviewed the literature regarding the advantages and disadvantages of this system of classifying the nutrients in feeds and added their objections to those of others who feel that the subdivision of the carbohydrates in feeds into crude fiber and nitrogen-free extract is inadequate. The main basis for this division is that crude fiber is designed as a measure of the fibrous, relatively poorly digested parts of plant material, while the nitrogen-free extract is designed to represent the more readily digested fraction including starch and sugars. Most of the evidence indicates that lignin is resistant to the digestive processes even in the ruminant, so the work of Norman (1935), demonstrating that crude fiber and nitrogen-free extract fractions vary considerably in lignin content with most of the lignin found in the latter fraction, is in itself a serious criticism of this system of analysis. Another objection lies in the finding that the digestibility of the crude fiber is often found to be as complete as for nitrogen-free extract (Crampton and Maynard, 1938).

In the attempt to devise a more rational scheme of analysis, Crampton and Maynard (1938) proposed that the carbohydrates of a feed be partitioned into cellulose, lignin, and "other carbohydrates" and presented methods for these determinations, the last named fraction being determined by difference. The objection raised that the crude fiber fraction does not represent a definite chemical entity can also be raised with respect to the proposed scheme. While cellulose is a reasonably well defined entity, lignin is not, and methods for its determination are necessarily based to some extent on empiricism. Possibly not all of the lignin is isolated from plant material by the 72 percent H_2SO_4 method to be described, yet the authors feel that lignin offers a better measure of the indigestible fraction of plant materials than does crude fiber. It also means that the value of a particular lignin procedure is best judged on the basis of both biological and chemical evidence.

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Literature

A discussion of the chemistry of lignin, a controversial subject, will not be included since Hibbert (1942) has recently reviewed this subject. Most methods for the determination of lignin involve the decomposition or solution of all associated substances in 72 percent H_2SO_4. After this treatment, the mixture is usually diluted with water to an acid concentration of 3 to 4 percent and boiled to complete the hydrolysis of cellulose and other carbohydrates. There are several factors which increase the lignin yield by this procedure:

(a) Increasing the temperature or the length of the 72 percent sulfuric acid treatment, Sherrard and Harris (1932), Ritter, *et al.* (1932).

(b) The presence of carbohydrates, especially pentoses, Norman and Jenkins (1934).

(c) The presence of proteins, Norman and Jenkins (1934).

(d) An increase in the temperature at which the sample of feed is dried, MacDougall and DeLong (1942).

The influence of temperature and length of the sulfuric acid treatment is minimized in the absence of carbohydrates, so it is particularly important to remove this source of interference. Norman and Jenkins (1934) recommended the removal of pentosans by dilute acid hydrolysis previous to the strong acid treatment. With respect to (c), the main difficulty in the case of forages and feces is the removal of protein without simultaneous removal of lignin. Crampton and Maynard (1938) used a peptic digestion while Manning and DeLong (1941) and Norman and Jenkins (1934) suggested that digestion with dilute acid is equally efficacious. Davis and Miller (1939), on the other hand, showed that an enzyme pretreatment removed more nitrogen from redtop grass than an acid pretreatment. The work of Cohen and Harris (1937) shows that with maple wood, hot water extraction removes a small fraction of lignin, while further treatment with boiling 3 percent H_2SO_4 removes even more lignin. If this is true for other plant materials, these losses must be incurred to avoid errors of greater magnitude due to the presence of substances removed by dilute acid pretreatment. Ross and Hill (1929) found that lignified tissues would dissolve more readily in 72 percent H_2SO_4 if first moistened with formalin and suggested that by blocking the reactive groupings of the lignin by the deliberate formation of a lignin-aldehyde resin, interference by other substances would be minimized. The Ross-Hill (1929) technique was adapted to the determination of lignin in plant materials by Crampton and Maynard. That this procedure is not desirable for plant materials is demonstrated by Manning and DeLong (1941) who found that it yielded higher results than the 72 percent H_2SO_4 method used by them, even though nitrogen retention by the lignin obtained by the two methods was approximately the same. The duration of the 72 percent H_2SO_4 treatment

and the temperature at which it is carried out both influence the yield of lignin, and various times and temperatures have been chosen by various workers generally to give the lowest yield. Typical treatments are for 2 hours at 20°C. (Ritter, *et al.*, 1932) and 16 hours at 10°C. (Sherrard and Harris, 1932).

MacDougall and DeLong (1942) made the important observation that the initial drying temperature affects the lignin yield, particularly in the case of succulent or immature tissues. Using a 72 percent H_2SO_4 method, they compared air drying, drying in vacuo at 60°C., air drying after extraction with cold water and cold dilute ethanol, and oven drying at 105°C. The latter drying procedure resulted in higher yields of lignin, the nitrogen and methoxyl content of which indicates the inclusion of nitrogenous and carbohydrate materials or both.

The choice of the procedure for the determination of lignin to be presented was based on two premises. The first is that the procedure yielding the lowest results is most desirable with the qualification that only generally accepted steps be involved and that the method be convenient to use. The second is that lignin is completely undigested by herbivorous animals. This latter premise is important not only because most of the available evidence indicates that this is true, but because it then becomes possible to calculate the digestibility of other feed constituents by determining the ratio of lignin to other nutrients in feeds and fecal matter without a knowledge of the quantity of feed ingested or of feces excreted.

Experimental Procedures and Results

It was decided to study the effect of various pretreatments, including the effect of initial drying temperature. Following the various pretreatments, the resultant residue was treated with 72 percent H_2SO_4 for 2 hours at 20°C. except in some instances where the Ross-Hill procedure was used. The directions followed for this procedure were as given by Crampton and Maynard. For the sake of convenience, the latter procedure is designated the formalin method while the former is designated the 72 percent H_2SO_4 method. In tables 1 and 2, two pretreatments are compared—one as given by Crampton and Maynard, the other as given in the A.O.A.C. (1940), which is the procedure developed by Phillips and his associates (1932, 1935, 1936). The lignin values given have been corrected for ash content.

The data presented in table 1 show that with the mature lespedeza hay the temperature at which the sample is dried has little or no influence on lignin yield, while with the young barley clippings, the drying temperature is an important factor, thus confirming the conclusions reached by MacDougall and DeLong (1942). The magnitude of the temperature effect depends to a considerable extent on other factors. For example, the higher

drying temperature gives a yield of 10.7 percent lignin contrasted to a yield of 6.7 percent at the lower temperature when the formalin method of isolation is used in conjunction with the A.O.A.C. pretreatment. While the differences are less marked in the other instances, the lower drying temperature results in lower lignin yields in every case. It is also evident that the

TABLE 1. EFFECT OF INITIAL DRYING TEMPERATURE ON YIELD OF LIGNIN OBTAINED BY VARIOUS PROCEDURES

Sample	Conditions of determination		Lignin[1]	
	Pretreatment	Method of isolation	Oven dried, 105°C. (dry matter) basis)	Vacuum dried, 60°C. (dry matter basis)
			percent	*percent*
Mature Lespedeza hay	C&M[2]	Formalin	17.25 (2)[1]	17.03 (2)
	A.O.A.C.	Formalin[3]	15.76 (2)	15.30 (3)
	A.O.A.C.	72% H_2SO_4	13.85 (4)	13.44 (3)
Young barley clippings	C&M	Formalin	5.44 (3)	4.48 (3)
	A.O.A.C.	Formalin	10.64 (2)	6.70 (2)
	A.O.A.C.	72% H_2SO_4	5.68 (2)	4.43 (2)

[1] The mean value is given. The number of determinations is shown in parentheses.
[2] According to Crampton and Maynard.
[3] One-half the amount of formalin called for in the Ross-Hill procedure.

TABLE 2. A COMPARISON OF THE A.O.A.C. AND CRAMPTON-MAYNARD PRETREATMENTS UNDER VARIOUS CONDITIONS

Sample	Conditions of determination		Lignin[2]	
	Method of isolation	Drying temperature	Pretreatment, C&M[1] (dry matter basis)	Pretreatment, A.O.A.C. (dry matter basis)
			percent	*percent*
Mature Lespedeza hay	Formalin[4]	105°C.	15.35 (1)[3]	15.39 (2)
	Formalin[3]	105°C.	15.39 (3)	15.76 (2)
	72% H_2SO_4	105°C.	13.66 (1)	13.85 (4)
Young barley clippings	Formalin[3]	105°C.	5.42 (2)	10.64 (2)
	72% H_2SO_4	105°C.	4.43 (3)	5.68 (2)
	Formalin	60°C.	4.48 (3)	6.70 (2)

[1] According to Crampton and Maynard.
[2] The mean value is given. The number of determinations is shown in parentheses.
[3] One-half the amount of formalin called for in the Ross-Hill procedure.
[4] With no formalin.

formalin method of isolation gives higher yields than the 72 percent H_2SO_4 method, this being particularly evident with young barley dried at 105°C. and given the A.O.A.C. pretreatment. Although the Crampton-Maynard pretreatment-formalin isolation procedure yielded low results with the

TABLE 3. OUTLINE OF VARIOUS MODIFICATIONS AND LIGNIN VALUES OBTAINED

Treatment	Scheme No.						
	I	II	III	IV	V	VI	VII
Ethanol-benzene extraction	30 hours	4 hours	30 hours	30 hours	4 hours	4 hours	4 hours
Hot water extraction	3 hours	1 hour	—	—	—	—	—
Peptic digestion	—	—	Overnight	—	Overnight	—	Overnight
Papain digestion	—	—	—	Overnight	—	Overnight	—
Dilute acid extraction (hot)	1% HCl 3 hours	1% HCl 1 hour	1% HCl 3 hours	1% HCl 3 hours	1% HCl 1 hour	1% HCl 1 hour	5% H_2SO_4 1 hour
72% H_2SO_4 treatment	2 hours at 20°C.	Same	Same	Same	Same	Same	Same
Acid digestion hot 3% H_2SO_4	3 hours	2 hours	3 hours	3 hours	2 hours	2 hours	2 hours
Lignin percent[1] Immature oat clippings	4.30 (4)	5.70 (3)	2.53 (3)	4.38 (2)	2.88 (3)		2.62 (4)
Mature Lespedeza hay	14.30 (2)		12.09 (3)	13.76 (2)	13.33 (3)	12.68 (2)	12.22 (3)

[1] The mean value is given. The number of determinations is shown in parentheses. Lignin is in percent (air dried basis). Weight of sample, one gram.

young plant material, this is not true of the hay sample where this procedure gave the highest results. Examination of the data given in table 2 shows that with the mature hay the pretreatment used has no appreciable influence on lignin yield. With the immature sample, the A.O.A.C. pretreatment gives higher results than does the Crampton-Maynard pretreatment. To obtain the lowest yield, it is evident that a low initial drying temperature, a Crampton-Maynard pretreatment, and the 72 percent H_2SO_4 method of isolation would be indicated.

The results of further studies of various modifications as indicated in table 3 show that a digestion with papain yields, in general, higher results than does a peptic digestion with these particular samples. They show also that a 4 hour extraction with the ethanol-benzene mixture gives almost as

low a lignin yield as a 30 hour extraction. The lowest results are given by scheme III (table 3), but in view of the small differences between these results and those given by scheme VII, which requires considerably less total elapsed time for an analysis, the latter scheme was adopted. This method which is presented in detail below gives lignin values that check within 2 mgs. of each other with samples ranging in weight from 0.5 to 2 gms.

Detailed Description of Lignin Method

Weigh one gram of air dried material ground to pass a 40 mesh screen into a coarse porosity alundum extraction thimble and extract the sample with an ethanol-benzene mixture (32 parts 95 per cent ethanol to 68 parts by weight of benzene) for 4 hours. Then with the aid of suction wash the sample in the thimble with two small portions of 95 per cent ethanol followed by two small portions of ether. Heat at 45°C. in a non-sparking oven to drive off all ether and transfer the sample to a 50 ml. glass-stoppered Erlenmeyer flask. Add 40 ml. of 1 percent pepsin (U.S.P. grade) in 0.1 N HCl and incubate at 40°C. overnight, shaking the flask a few times during the first hour to insure thorough mixing. The next morning transfer the residue to a 250 ml. wide-mouth Erlenmeyer flask with the aid of a stream of hot distilled water. Filter,[2] add 20 to 30 ml. of hot water, and again filter. Wash the residue in this manner three times. After the last filtration, force 7 to 8 ml. of 5 percent (by weight) H_2SO_4 solution downward through the filter stick with the aid of air pressure, thus washing the residue from the stick into the flask. Wash the stick further with 5 percent H_2SO_4 and add a sufficient volume to bring the total to approximately 150 ml. After refluxing[3] for one hour, the acid is filtered off. Wash the residue three times with 20 to 30 ml. portions of hot distilled water, twice with 15 to 20 ml. portions of 95 percent ethanol, and twice with 15 ml. portions of ether. After the final ether washing, leave the vacuum on a few minutes to dry the residue. By tapping and brushing remove the residue from the filter stick leaving it in the same flask. Evaporate residual ether in oven at 45°C. Some immature plant materials dry from ether into disks difficult to break up into a finely divided state. In these cases wash down the filter stick with ether and disperse the residue in the ether

[2] Filtration is carried out with a filter stick usually referred to as an immersion tube with fritted glass disk by most supply houses. The authors use a pyrex, 30 mm. diameter, medium porosity type. A row of 12 filter sticks for simultaneous use is set up using six student model, double burette holders. An 18 cm. length of 10 mm. glass tubing fitted with a 5 cm. side arm near the upper end, projecting at an upward angle, fits into the burette clamp and is connected to the vacuum line at the top by rubber tubing and joined at the bottom with a short section of rubber tubing to the filter stick. The purpose of the side arm is to facilitate the introduction of liquids into the inside of the filter stick for thorough washing off of solids from the fritted disk. Since the authors have found that about one-third of the filter sticks as purchased are unsatisfactory, it is advisable to purchase more than needed and discard those that do not filter well. The filter sticks are coated with pre-ashed diatomaceous earth (hyflo Supercel, Johns-Manville, N. Y.) by suspending some in water and sucking on a thin layer with vacuum. This usually is sufficient for easy filtration; if not, extra Supercel added to the residue being filtered will often help.

[3] An ASTM extraction apparatus is used for all refluxing operations.

before evaporating it on a steam bath. To the residue add 20 ml. of 72 percent H_2SO_4 (by weight) at 20°C. and hold at 20°C. for 2 hours with occasional stirring. Then add 125 ml. of water,[4] filter, wash once with a 15 to 20 ml. portion of hot water and again filter. Wash residue from the filter stick as before with 3 percent H_2SO_4 making the volume to 150 ml. and reflux 2 hours. Filter the residue into a Gooch or an alundum crucible and wash the residue with hot distilled water until free of acid. Dry at 105° to 110°C. and determine lignin by loss of weight on ignition at 600°C.

Animal Studies

The data obtained from a limited number of digestion trials[5] indicate that lignin is not digested by the cow, sheep, and rabbit. The results are summarized in table 4. Since lignin is apparently not digested, the lignin values in feeds and feces may prove useful in determining the coefficient of digestibility of other feed constituents.

TABLE 4. PERCENT RECOVERY OF LIGNIN IN DIGESTION TRIALS

Ration	No. of animals and species	Percent recovery of lignin, with standard error
Timothy hay, beet pulp, and concentrate mixture	4 cows	102.6±2.51
Sudan grass unfertilized	6 rabbits	95.0±1.94
Sudan grass fertilized (superphosphate)	5 rabbits	99.6±1.82
Sudan grass unfertilized	6 sheep	106.0±1.08
Sudan grass fertilized (superphosphate)	6 sheep	94.0±1.81

A convenient formula indicating the necessary calculations is shown below.

$$y = 100 - 100 \frac{x}{z} \cdot \frac{n \text{ in feces}}{n \text{ in feed}}$$

y = percent digestibility of a specific nutrient, n
n = percent of a specific nutrient in either feed or in feces
x = percent lignin in feed
z = percent lignin in feces

[4] Most procedures recommend dilution of the 72 percent H_2SO_4 to a strength of 3 percent. The procedure given results in the same lignin yield, shortens filtration time and avoids the use of another flask.

[5] The samples from the digestion trials with cows were obtained through the courtesy of H. L. Lucas and J. K. Loosli (cf. JOUR. OF ANIMAL SCIENCE, 3: 3–11, 1944).

TABLE 5. DIGESTION COEFFICIENTS AND THEIR STANDARD ERRORS OF FOUR RATIONS AS DETERMINED BY DIGESTION TRIALS AND LIGNIN RATIOS

Ration	No. of animals, and species	Method of determination	Digestion coefficients					
			Dry matter	Crude protein	Crude fiber	N.F.E.	Cellulose	Other carbohydrates
Timothy hay, beet pulp, & concentrate mixture	4 cows	Conventional	69.0±0.52	68.6±0.58	57.5±1.31	77.2±0.49	64.3±0.76	86.5±0.66
		Lignin	69.9±0.41	69.4±0.97	58.7±0.89	77.8±0.19	65.3±0.72	86.9±0.44
Sudan grass unfertilized	6 rabbits	Conventional	32.1±1.46	61.6±1.93	12.6±2.07	32.7±1.54	16.5±2.08	45.7±1.01
		Lignin	28.1±1.29	59.4±1.73	7.3±2.73	28.9±0.67	11.6±1.58	42.4±1.94
Sudan grass fertilized (superphosphate)	5 rabbits	Conventional	29.7±1.01	60.6±1.03	9.1±2.14	33.1±0.76	11.3 ±2.16	49.0±0.70
		Lignin	29.1±1.02	60.4±1.10	8.8±2.01	32.9±0.52	11.0 ±1.81	48.9±1.01
Sudan grass unfertilized	6 sheep	Conventional	62.7±0.34	64.8±0.40	69.9±0.64	57.4±0.41	72.4 ±0.59	68.5±0.58
		Lignin	*60.3±0.66	62.3±0.87	68.4±0.65	**54.7±0.67	70.9 ±0.55	66.4±0.96
Sudan grass fertilized (superphosphate)	6 sheep	Conventional	62.0±0.40	62.8±0.73	68.3±0.58	58.6±0.24	69.7 ±0.45	73.1±0.41
		Lignin	*64.0±0.72	64.9±0.99	*70.3±0.77	*61.0±0.70	*72.0 ±0.68	74.7±0.73

* Difference is significant at the 5 percent level.
** Difference is significant at the 1 percent level.

This method of determining digestibility coefficients will be referred to as the lignin ratio method. Several investigators have proposed the ratio technique for determining digestibility. Nearly twenty years ago, Bergeim (1926) used ferric oxide as a reference material, and recently Gallup, *et al.* (1945) reported extensive investigations using silica.

Using the ratio technique, the digestibility of feeds may not only be determined without measuring feed intake or fecal output but permits studies of the digestibility of pasture herbages under grazing conditions. In connection with pasture studies, it is also evident that the feed consumption can be measured provided the feces are quantitatively collected. The difficulty of obtaining a representative sample of pasture herbage should not prove insurmountable.

Coefficients calculated in this way (table 5) have been compared with those obtained in the conventional way for the various nutrients in feeds, using data from the digestion trials performed on the twenty-seven animals mentioned previously. Of the thirty comparisons one shows a statistically significant difference at the 1 percent level and four at the 5 percent level. These differences are of small magnitude and are indicated in the table. They are found in the two trials with sheep where the recovery of lignin was 106 percent in one group and 94 percent in the other. No explanation for this difference in the recovery of lignin is offered. It is apparent from the data in table 5 that the standard errors of the digestion coefficients as determined by the two methods are not significantly different. This indicates that the variability of the digestion coefficients of the two methods is of the same magnitude.

Daily Variation of Lignin Content in Feces

In using the lignin ratio technique for determining the digestibility of feedstuffs, the question arises as to how many daily collections of the feces should be made to insure a representative fecal sample. The data in table 6 demonstrate that the daily variation in lignin content of feces from sheep on a diet of timothy hay is remarkably small.

Three sheep quartered in a large pen were fed ad lib on a diet of timothy hay. Until the experiment started, the sheep had been fed a diet of grain and timothy hay. On the ninth day of the experimental period, collection bags were placed on the sheep and daily fecal samples were taken for nine consecutive days. In taking the daily fecal samples, no effort was made to obtain a representative sample of the 24 hours fecal output. Only the first approximate 75 gms. of the feces taken from the collection bags were used. Each day the fecal sample was placed in an evaporating dish, wetted down

with 95 percent ethanol, dried at 55°C. for 48 hours, and ground to pass a 40 mesh screen.

The small daily variation in lignin content of the feces suggests that a three to four day collection should insure an adequate representative sample

TABLE 6. THE DAILY VARIATION IN LIGNIN CONTENT OF FECES FROM THREE SHEEP FED TIMOTHY HAY (ON DRY MATTER BASIS)

Date collected	Lignin content for sheep number		
	1	2	3
	percent	*percent*	*percent*
11/10/44	24.3	23.2	23.8
11/11/44	24.3	23.1	23.7
11/12/44	24.8	22.7	22.4
11/13/44	24.5	23.3	22.6
11/14/44	24.7	23.0	22.8
11/15/44	24.6	23.2	22.4
11/16/44	24.4	23.1	23.7
11/17/44	24.1	23.1	23.3
11/18/44	25.6	23.3	23.1
Mean and standard error	24.6±0.13	23.1±0.08	23.1±0.18

of feces for use in applying the lignin ratio technique to the determination of the digestibility of hay by this species.

A Comparison of the Modified Scheme with the Standard Feedingstuff Analysis

The digestibility coefficients of the carbohydrate fractions of the feeds used in the digestion trials have been summarized in table 7 along with the composition of the diets. The carbohydrate fraction has been subdivided according to the standard A.O.A.C. method into crude fiber and N. F. E. (nitrogen-free extract) and into cellulose,[6] lignin, and "other carbohydrates" according to the scheme proposed by Crampton and Maynard and others. It should be noted that "other carbohydrates" includes a smaller fraction than does N. F. E. Not only does the proposed method analyze directly for a greater proportion of the feed, but it makes a clearer distinction between fractions with respect to digestibility. In all cases, the digestibility of the "other carbohydrates" is considerably greater than that of nitrogen-free extract.

[6] The cellulose determinations were made by a modification of the Norman-Jenkins method described elsewhere in this Journal.

TABLE 7. CHEMICAL ANALYSES OF THE CARBOHYDRATE FRACTIONS OF VARIOUS RATIONS BY TWO SCHEMES

Ration	No. of animals and species	Standard method		Proposed method	
		Composition, %	Coefficient of digestibility with standard error	Composition, %	Coefficient of digestibility with standard error
Timothy hay, beet pulp and concentrate mixture	4 cows	N.F.E.* 56.60 Crude fiber 21.60 TDN	77.0±0.53 57.5±1.26 69.1±0.80	Other CHO* 44.44 Cellulose 27.60 Lignin 6.19 TDN	86.5±0.66 64.3±0.76 −2.6±2.51 69.2±0.68
Sudan grass unfertilized	6 rabbits	N.F.E. 43.83 Crude fiber 34.11 TDN	32.7±1.54 12.6±2.07 27.9±1.34	Other CHO 23.37 Celulose 45.19 Lignin 9.38 TDN	45.7±1.01 16.5±2.08 +5.0±1.94 27.5±1.28
Sudan grass fertilized (superphosphate)	5 rabbits	N.F.E. 44.70 Crude fiber 34.75 TDN	33.1±0.76 9.1±2.14 26.9±1.31	Other CHO 26.26 Cellulose 44.35 Lignin 8.83 TDN	49.0±0.70 11.3±2.16 + .4±1.82 26.8±1.06
Sudan grass unfertilized	6 sheep	N.F.E. 42.84 Crude fiber 34.18 TDN	57.4±0.41 69.9±0.64 59.0±0.08	Other CHO 22.26 Cellulose 45.08 Lignin 9.67 TDN	68.4±0.96 72.4±0.59 −6.0±1.08 58.4±0.07
Sudan grass fertilized (superphosphate)	6 sheep	N.F.E. 45.68 Crude fiber 34.62 TDN	58.6±0.24 68.3±0.58 59.8±0.51	Other CHO 26.57 Cellulose 44.83 Lignin 8.65 TDN	74.7±0.73 69.7±0.45 +6.0±1.81 60.1±0.40

* Calculated by difference.

Discussion

New schemes for the analysis of feedingstuffs to replace the method now generally used throughout the world have not been given ready acceptance. Only when a new scheme has been proven of value when applied to a great many animal studies can any confidence be gained. Unless the methods of analysis recommended are relatively easy to perform and inexpensive with respect to apparatus and time, these methods will not be given a good trial. Thus, the method of lignin analysis developed by Phillips and his associates, while undoubtedly a good method, has not been widely accepted because it is not readily adapted to routine analyses.

The methods of cellulose and lignin analysis recommended by Crampton and Maynard, on the other hand, do meet the requirements of routine methods but have been found not to be generally applicable to animal studies (Crampton and Whiting, 1943). The belief on the part of the authors that the Norman-Jenkins cellulose method is better for feed analysis than

the method recommended by Crampton and Maynard has been discussed elsewhere (Matrone, Ellis and Maynard, 1946), and a modified Norman-Jenkins method for the determination of cellulose applicable to routine work has been given. The present paper presents a 72 percent H_2SO_4 lignin method which also is adaptable to routine work. The value of these methods will have to await their application to a number of animal studies. The limited data presented indicate that these methods may prove useful.

Summary

A procedure for the routine determination of lignin in feedstuffs is given. Studies with the cow, sheep, and rabbit indicate that lignin as determined by this method is not digested.

A lignin ratio technique for the determination of the digestibility of feedstuffs is described, and data are presented to show the reliability of this technique.

The use of lignin and of cellulose values in a scheme for the analysis of feedstuffs is discussed in the light of data obtained from digestion trials with animals.

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VARIATION IN DETERMINATIONS OF DIGESTIVE CAPACITY OF SHEEP[1]

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IN CONNECTION with a program of measurement of pasture values in terms of the digestible nutrients of cut and dried forage fed to sheep under conditions of laboratory control, it was desired to know how many sheep would be needed for each determination of digestibility—in consideration of the variability of the individual determinations, and with the understanding that this variability as observed would cover not only the physiological function of interest but also all factors of technic involved.

Materials and Methods

Accordingly, twenty-five yearling Merino wethers were purchased to serve as subjects of a digestion experiment on a single kind of hay. These sheep had been on pasture, without grain. They appeared to be in good health, and they weighed from 63 to 90 pounds, with an average of 74 pounds.

In order that sheep shall be able to maintain their weight on hay alone it is necessary that this hay be of excellent quality. It was our idea, therefore, to use No. 1 alfalfa in this test; but under the conditions existing it was impossible to obtain such hay.

The best hay available was mixed clover-timothy hay, of excellent quality, the composition of which, as analyzed in three lots, was as given in table 1. These three lots of hay were all from the same field, the differences in composition presumably representing somewhat different proportions of clover and timothy.

The usual feeding stuff analysis was made by standard procedures, and the determinations of soluble carbohydrate, cellulose, and lignin by difference, by the procedures suggested by Crampton and Whiting (1943). Lignin was also determined, more directly, by the 72 percent sulphuric acid method carried out essentially as specified by Ellis, Matrone and Maynard (1946), but modified in detail as required by the fact that the filter sticks and porous alundum thimbles used with obvious advantage by Ellis, *et al.*, were not available.

Since the method of drying the product to be analyzed is pertinent in any

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method of determination of lignin, it is to be noted that in the present experiment the hay was sun-dried while the feces were dried in an air oven at 65°C.

The daily hay consumption per 100 lbs. live weight averaged from 961 to 1,227 grams, the general average being only 1,060 grams, or 2.33 pounds. Sheep will not eat as much hay when confined in digestion crates as when free to move about, and the quantity of clover-timothy hay eaten in the digestion crates in this experiment was not sufficient to maintain the initial live weight. It therefore became apparent that in a program of determina-

TABLE 1. COMPOSITION OF THE CLOVER-TIMOTHY HAY FED

Sheep Nos.	Dry matter	Crude protein	Crude fiber	Ether extract	N-free extract	Ash	Gross energy	Soluble carbohydrate	Cellulose	Lignin*	Lignin**
	per cent	per cent	per cent	per cent	per cent	per cent	cal. per gm.	per cent	per cent	per cent	per cent
1, 5, 6, 7, 9	90.87	12.81	31.38	3.50	36.80	6.38	4092	39.63	26.31	11.38	9.08
4, 8, 21–25	91.49	13.25	30.60	3.39	37.55	6.70	4146	39.20	27.66	9.81	9.15
11–20	91.37	13.19	30.43	3.15	37.98	6.62	4138	39.99	25.95	11.10	9.16

* Determined by difference, as proposed by Crampton and Whiting (1943).

** Determined by the 72 percent sulphuric acid method as modified by Ellis, Matrone and Maynard (1946).

tions of the digestible nutrients of miscellaneous forages, with sheep as subjects, these forages should be of unusually good quality, for instance as resulting from machine drying, or there would need to be intermediate periods of feeding, between the digestion periods, in which the sheep would receive concentrate feeds with their roughage.

Accordingly, each sheep used in this test was given one-half pound daily of a mixture of equal parts of shelled corn, oats and wheat bran in addition to roughage, ad libitum, when not in the digestion crates. On this treatment they made good the losses sustained during the digestion trials, and in addition made slight gains in weight.

Since nearly all sheep are parasitized, and since heavy infestation with parasites affects the digestive capacity, if this test was not to be, in effect, a study of relative parasitic infestation, it was necessary to subject the sheep to a preliminary anthelmintic treatment in order to reduce the parasitism to the lowest practicable degree. In preparation for the digestion program, therefore, the sheep were each given a drench of 4 oz. of a preparation of phenothiazine and bentonite, and a second such treatment one month later. The 4 oz. dose contained 25 grams of phenothiazine.

During the interval between these treatments, and subsequently, the

sheep had free access to a 1:9 mixture of phenothiazine and salt, but while in the digestion crates the salt received was unmixed with phenothiazine.

Two counts of the parasite eggs in the feces of the sheep were made,[2] one after the two phenothiazine treatments, and the other at the end of the digestion experiment.

Three sheep, Nos. 2, 3 and 10, were dropped from the experiment because of deficient and irregular feed consumption. No parasite eggs were found in the feces of No. 2; No. 3 was lightly parasitized; while the first examination of No. 10 revealed no parasite eggs, and at the second examination only one parasite egg per gram of feces was found. Sheep No. 10 was then killed, for examination, and the condition of its intestine showed that it must have been heavily infested with nodular worms prior to the phenothiazine treatment; and, on account of the resulting damage to the intestine, this sheep would have been unable to survive on the amount of clover-timothy hay that it would eat in a digestion crate.

It was the judgment of the veterinarian that the degree of parasitism found in the sheep after the two phenothiazine treatments was about as low as could be expected from any known anthelmintic treatment.

In this test the preliminary and the collection periods were each 10 days in length, and the sheep were confined to the digestion crates during the entire 20 days.

The digestion crate employed was copied from one designed by Watson.[3] In the use of this crate, however, it was found desirable to employ a harness and feces bag of our own design, rather than the apron and pan used by Watson, for the collection of the feces. With this bag the collection was perfect, without an attendant being present.

The feces were dried at 65°C. in an air oven for 24 hours, and then allowed to come into equilibrium with the moisture content of the air before being weighed, ground and bottled for analysis. This drying was shown to be sufficient by the fact that the feces gained in weight while coming into equilbrium with the moisture content of the air; and it was demonstrated that, with the ration used, there was no loss of nitrogen during this drying of the feces at 65°C. for 24 hours.

It was determined by trial that the gross energy value of the urine of the sheep on the particular ration employed could be computed (in kilogram calories) with an accuracy sufficient for use in computing metabolizable energy by multiplying its nitrogen content in grams by the factor 20.0.

A slight element of imperfection in this investigation resulted from the

[2] The authors are indebted to Dr. W. T. M. Thorp for the conduct of this phase of the experiment.
[3] Dr. Cyril J. Watson, Central Experimental Farm, Ottawa, Canada.

refusal, and the scattering, of small amounts of feed by the sheep. This waste feed was collected and subjected to chemical analysis, and its constituents were subtracted from the constituents of the feed weighed to the sheep. This involved such slight error as existed in the implied assumption that the amounts of nutrients actually consumed were the same in the 10-day preliminary period as in the following 10-day period of excreta collection.

Results

In table 2 are given the live weights of the sheep at the beginning of the ten-day digestion experiment, and the daily amounts and constituents of the clover-timothy hay eaten by the sheep during this test.

TABLE 2. LIVE WEIGHT OF SHEEP, AND THE DAILY AMOUNTS AND CONSTITUENTS OF CLOVER-TIMOTHY HAY EATEN DURING THE TEN-DAY DIGESTION EXPERIMENTS

Sheep Nos.	Live weight	Dry matter	Crude protein	Ether extract	Crude fiber	N-free extract	Gross energy	Soluble carbohydrate	Cellulose	Lignin*	Lignin**
	lbs.	gm.	gm.	gm.	gm.	gm.	kilocal.	gm.	gm.	gm.	gm.
1	86.5	772	109	30	266	313	3475	336	223	97	77
4	81.0	730	106	27	244	300	3309	313	221	78	73
5	88.5	895	127	35	308	363	4028	390	259	112	89
6	92.5	894	127	35	307	362	4023	389	258	112	89
7	78.5	776	109	30	267	314	3492	338	224	97	78
8	77.0	819	119	30	274	336	3711	351	247	88	82
9	80.0	779	110	30	269	316	3509	340	226	98	78
11	71.5	683	99	24	227	284	3093	299	194	83	69
12	88.0	856	124	30	284	356	3878	375	242	104	86
13	75.5	678	98	23	225	282	3073	297	192	83	68
14	76.5	858	124	30	285	357	3885	375	243	104	86
15	72.5	763	111	27	253	318	3458	334	216	93	76
16	72.5	763	111	27	253	317	3456	334	216	93	76
17	75.0	672	98	23	223	280	3045	294	190	82	67
18	75.5	671	98	23	222	279	3040	294	190	82	67
19	74.0	760	110	26	253	316	3440	333	216	93	76
20	77.5	681	98	24	226	283	3083	298	193	83	68
21	78.5	721	105	27	241	296	3267	309	218	77	72
22	86.5	818	119	30	273	336	3707	351	247	88	82
23	77.5	714	104	27	238	294	3237	306	216	77	71
24	85.0	822	119	30	275	337	3724	352	248	88	82
25	91.5	911	132	34	305	374	4130	391	276	98	91

* Determined by difference, as proposed by Crampton and Whiting (1943).

** Determined by the 72 percent sulphuric acid method as modified by Ellis, Matrone and Maynard (1946).

The amounts of hay eaten, which were the maximum that the sheep would clean up, were in each case insufficient to maintain the live weights of the subjects.

It will be observed that the determinations of lignin by difference and by the 72 percent sulphuric acid method do not yield equivalent results.

The individual data for coefficients of digestibility and for metabolizable energy of the clover-timothy hay are given in table. 3. The variability of these determinations was satisfactorily low except for the digestibility

TABLE 3. COEFFICIENTS OF DIGESTIBILITY, DIGESTIBLE NUTRIENTS AND METABOLIZABLE ENERGY OF CLOVER-TIMOTHY HAY

Sheep Nos.	Dry matter	Crude protein	Ether extract	Crude fiber	N-free extract	Energy	Soluble carbo-hydrate	Cellu-lose	Lignin*	Lig-nin**	Total dig. nutr.	Metab. energy per kg. D.M.
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*calories*
1	58.5	58.3	70.8	56.4	62.2	55.9	72.1	61.2	28.4	2.5	53.6	1716
4	58.6	60.6	66.3	53.6	64.0	56.7	70.2	61.6	17.2	−1.8	53.5	1744
5	56.4	56.7	70.8	54.8	58.8	54.5	71.5	57.7	28.1	−2.7	51.7	1709
6	55.9	54.7	68.5	52.9	60.2	53.6	70.5	56.0	32.5	−2.4	51.2	1677
7	58.5	57.1	69.6	54.6	63.8	56.6	72.4	60.0	34.2	−1.9	53.4	1755
8	58.0	61.0	67.0	52.1	63.3	55.6	71.1	60.6	13.3	−3.4	52.9	1734
9	57.9	56.3	69.7	53.3	63.6	55.5	71.0	60.4	28.9	− .4	52.8	1719
11	58.9	61.4	62.1	54.3	63.0	56.2	72.3	59.6	26.6	2.8	53.0	1709
12	57.3	58.1	67.2	49.6	64.5	54.8	70.4	58.1	26.6	3.5	52.0	1714
13	56.8	59.8	63.7	51.9	61.9	54.0	70.4	58.7	21.5	− .6	51.7	1597
14	57.9	59.1	64.9	53.0	62.9	55.9	72.1	55.3	33.2	1.9	52.4	1760
15	56.9	56.5	65.7	53.4	62.1	55.3	72.3	57.6	25.2	− .5	51.9	1702
16	56.0	57.1	63.4	51.9	61.3	53.7	70.6	56.3	24.7	−3.4	51.1	1644
17	57.4	60.9	65.7	50.8	62.9	55.1	72.4	57.1	25.9	2.4	52.0	1640
18	57.0	56.4	63.1	51.3	63.9	54.8	72.1	57.4	23.1	−2.1	51.8	1633
19	57.2	56.8	65.6	53.0	63.2	55.3	70.6	57.8	28.2	−1.3	52.3	1712
20	56.7	59.8	64.3	50.4	62.2	54.5	68.8	52.8	32.2	2.8	51.4	1620
21	57.8	57.1	68.9	54.5	62.9	56.4	71.3	60.6	20.4	−2.9	53.1	1716
22	56.5	56.8	66.7	52.5	61.7	54.5	70.3	58.9	19.3	−1.1	51.9	1693
23	55.3	55.7	68.3	50.1	61.2	53.9	69.2	56.9	17.6	−2.5	50.9	1629
24	58.6	59.1	68.4	53.9	64.1	56.9	71.4	58.9	17.1	−3.3	53.6	1777
25	55.1	56.0	66.6	49.6	61.5	52.4	64.2	57.7	12.8	−6.8	50.8	1634
Average	57.2	58.0	66.7	52.6	62.5	55.1	70.7	58.2	24.4	−1.0	52.2	1693
Standard deviation	1.1	1.9	2.5	1.8	1.4	1.2	1.8	2.1	6.3	2.6	0.9	51

* Determined by difference, as proposed by Crampton and Whiting (1943).

** Determined by the 72 percent sulphuric acid method as modified by Ellis, Matrone and Maynard (1946).

values of lignin as determined by difference. The much greater variability of this observation than of any other could conceivably be due to a true difference of the kind indicated, but since the variability of digestibility of the nutrients involved in the complicated determination of lignin by difference (in which there are six steps) was very much less than that determined for lignin, it seems probable that the high variability of the apparent digestibility of lignin, determined by difference, resulted primarily from different

algebraic summations of experimental errors in the several determinations upon which the determination of lignin by difference depends.

The 72 percent sulphuric acid method as modified by Ellis, Matrone and Maynard (1946), gave lignin values usually varying but little from the average, the standard deviation being 2.6 percent.

Among the 22 results 6 imply slight digestibility, while with the remaining 16 sheep slightly more lignin appeared to be present in the feces

TABLE 4. RELATION BETWEEN THE VARIABILITY OF THE OBSERVED VALUES FOR DIGESTIBILITY AND METABOLIZABLE ENERGY OF THE NUTRIENTS OF CLOVER-TIMOTHY HAY AND THE NUMBERS OF SHEEP REPRESENTED

Number of sheep in each group	Digestible dry matter		Digestible crude protein		Digestible energy		Total digestible nutrients		Metab. energy per kg. dry matter	
	Standard error	Signif. diff. between means*	Standard error	Signif. diff. between means*	Standard error	Signif. diff. between means*	Standard error	Signif. diff. between means*	Standard error	Signif. diff. between means*
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*calories*	*calories*
1	1.09	3.0	1.95	5.4	1.16	3.2	.89	2.5	51	141
2	.77	2.1	1.38	3.8	.82	2.3	.63	1.8	36	100
3	.63	1.7	1.12	3.1	.67	1.9	.52	1.4	29	81
4	.55	1.5	.97	2.7	.58	1.6	.45	1.2	25	70
5	.49	1.4	.87	2.4	.52	1.4	.40	1.1	23	63
6	.45	1.2	.80	2.2	.47	1.3	.37	1.0	21	57
7	.41	1.1	.74	2.0	.44	1.2	.34	.9	19	53
8	.39	1.1	.69	1.9	.41	1.1	.32	.9	18	50
9	.36	1.0	.65	1.8	.39	1.1	.30	.8	17	47
10	.35	1.0	.62	1.7	.37	1.0	.28	.8	16	45

* Minimum difference required between mean values for odds of 19:1.

than in the feed. This slight apparent negative digestibility of lignin might conceivably have been caused by experimental error in the digestion tests, or by a chemical difference in the products determined as lignin in feed and feces—possibly due to the difference in the temperatures at which the feed and the feces were dried.

The metabolizable energy of the ration was computed, as usual, from the energy of the feed, the urine, the feces and the methane, methane being computed from digestible carbohydrate by the formula of Bratzler and Forbes (1940), which was derived from results of calorimetric experiments with cattle.

The average metabolizable energy of the hay was 1,693 Cal. per kilogram of dry matter, the standard deviation 51 Calories, and the coefficient of variation 3.0 percent.

Table 4 presents data expressing the variability of the observed values for digestibility of the nutrients of the clover-timothy hay for different numbers of sheep. In computing the minimum differences between the mean values for one to ten sheep that were necessary to yield odds of significance of 19 to 1, the standard errors of the means of results for one to ten were computed by dividing the standard error of a single variate computed from the data for the 22 sheep by the square root of the number of animals in each group. The probable error of the difference between two means of equal numbers of sheep was taken as the square root of the sum of the squares of the probable errors of the two means. Then, by use of standard tables giving the odds corresponding to various values of the ratio of a difference to its probable error, the amount of difference required for the chosen odds was computed.

In consideration of the method by which they were derived, the values comprising this table express a characteristic curvilinear series of results for each experimental determination. With an observed difference representing the same observation on two experimental lots, therefore, this table affords a basis for determining how many animals per lot are required to render significant the observed difference, to an extent expressed by odds of 19:1. Thus, in the interpretation of digestion experiments with sheep, the observed difference between values for digestibility of any constituent of two rations will be evaluated not alone by the number of sheep used, but also by the magnitude of the difference observed. In other words, the data presented in this table afford a basis of evaluation of differences in digestibility which may be obtained with different numbers of sheep as subjects.

Summary

In a study of variation in determinations of digestive capacity of sheep, 22 yearling Merino wethers were used as subjects in a digestion experiment with clover-timothy hay as the only feed.

The standard deviation of the values determined for digestibility of the nutrients of the hay were reasonably low except with reference to lignin as determined by difference.

A table is presented giving the standard errors and the minimum difference required between determinations with one to ten sheep for odds of significance of 19 to 1.

While the number of sheep required per experimental treatment depends on the permissible variability of results, it is concluded that five sheep per treatment are a sufficient number for usual purposes if the experimental technic is efficient, and if the sheep have been successfully treated on account of parasites of the alimentary tract.

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A MODIFIED NORMAN-JENKINS METHOD FOR THE DETERMINATION OF CELLULOSE AND ITS USE IN THE EVALUATION OF FEEDSTUFFS

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A PREVIOUS paper (Ellis, *et al.*, 1946) has dealt with a method for determining lignin and its uses in animal digestion studies. In this paper a method for determining cellulose is presented and its usefulness in animal nutrition discussed. This method is a modification of the Norman-Jenkins (1933) cellulose method. Although somewhat slower to run than the cellulose method of Kürschner and Hanak (1930) which has been adopted by Crampton and Maynard (1938) and others, it has certain advantages that deserve consideration. Before discussing these advantages, a brief review of the nature of cellulose in plant materials is in order.

Cellulose in the true chemical sense is a simple glucose polysaccharide $(C_6H_{10}O_5)_x$. Cellulose as found in most plants is in intimate association with other polysaccharides. Hawley and Norman (1932) proposed the term cellulosan to define hexosans or pentosans occurring intermixed with true cellulose in the natural cellulosic aggregate. The cellulosan in feedstuffs seems to be composed chiefly of xylan. Norman (1936b), (1937a) pictures the micelle as an intimate association of long chains of glucose units and shorter chains of xylose units. The x-ray work of Astbury, *et al.* (1935) supports the possibility of such an arrangement. In contrast to the earlier theory of Cross and Bevan which postulated "compound celluloses" such as lignocellulose, pentocellulose, etc., the present concept as expounded by Norman and Fuller (1942) is that "while it is unlikely that cellulose is chemically linked to its associates, primarily the polyuronide hemicelluloses and lignin, or that 'compound' celluloses occur, nevertheless, the normal structure is such that interpenetrating systems are found. The cellulosic fabric composed of oriented micellae is, as it were, interwoven with amorphous systems composed of lignin or polyuronide hemicelluloses, each of which may be removed by appropriate treatments leaving the others intact and still exhibiting the form of the tissue."

In this paper the terminology of Norman (1937b) will be followed. By "true" cellulose, Norman means the $(C_6H_{10}O_5)_n$ fraction and by cellulose, the natural cellulosic aggregate.

There is some evidence that the xylan cellulosans are digested to the same extent by animals as is "true" cellulose. Ferguson (1942) in studying the

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digestibility of wheat straw and wheat straw pulp by sheep, found that "true" cellulose is digested to the same extent as are the cellulosans. Thus, the cellulose of Norman and Jenkins may be a biological as well as a structural unit. Since the Crampton-Maynard (1938) method appears to remove most of the cellulosans (Kürschner and Hoffer, 1929; Ferguson, 1942; and data obtained in the present study, table 1), the advantage of the Norman-Jenkins over the Crampton-Maynard method appears clear. The chief difficulty in analyzing for cellulose is to remove the encrusting lignin and

TABLE 1. A COMPARISON OF CELLULOSE METHODS

Sample	Crampton & Maynard, (1938) (air dried basis)	Norman & Jenkins, (1933) (air dried basis)
	percent	*percent*
Sudan grass before heading	27.40	33.97
Immature oat hay	26.82	34.23
Corn stover (tetraploid)	26.50	32.79
Corn stover (diploid)	33.00	43.90
Timothy hay, mature	33.11	41.72
Lespedeza hay	30.69	31.90

polyuronide hemicellulose without removing the cellulosans. In the Norman-Jenkins method, this is accomplished by alternate chlorinations and boiling with dilute sulphite. The lignin reacts rapidly with chlorine and the lignone-chloride complex is readily dissolved in dilute sodium sulphite. Norman and Shrikhande (1935) suggest that the hemicellulose and lignin may be in some form of combination and that the solution of the hemicelluloses depends on the rupture of the linkage with lignin. Alkali treatment, chlorination, and oxidation of the lignin can rupture this association.

Experimental Procedures and Results

Method for the Determination of Cellulose

Weigh out a 1 gm. air dried sample ground to pass a 40 mesh screen and extract with a 95 percent ethanol-benzene mixture (1:2 by weight) for 3 or 4 hours. Transfer the residue to a 100 ml. pyrex beaker (tall form); add 50 ml. of 3 percent sodium sulphite and bring to a boil. Filter[2] and then add

[2] Filtration is carried out with a filter stick usually referred to by most supply houses as an immersion tube with fritted glass disk. The authors use a pyrex, medium porosity type of 30 mm. diameter. A row of 12 filter sticks for simultaneous use is set up using six student model, double burette holders. An 18 cm. length of 10 mm. glass tubing fitted with a 5 cm. side arm near the upper end, projecting at an upward angle, fits into the burette clamp and is

10 ml. of 0.25 N sodium hydroxide in approximately 60 percent ethanol (60 ml. of 95 percent ethanol to 40 ml. of water) washing out the filter stick with this solution. Stir thoroughly and neutralize with 1 ml. of 2.5 N sulfuric acid,[3] filter, wash the residue once with 20 to 30 ml. of hot distilled water and again filter. Leave the filter stick in the beaker and add 43 ml. of cold water and 7 ml. of sodium hypochlorite solution[4] (5.25 percent available chlorine). Allow to stand for 10 minutes with occasional stirring. Then filter off the hypochlorite solution, add 50 ml. of 3 percent sodium sulphite solution, and boil for at least 5 minutes (leave filter stick in beaker to decrease bumping). Filter off the hot sodium sulphite solution and repeat the 0.25 N ethanolic sodium hydroxide treatment exactly as before. After neutralizing and filtering, suspend the material in 50 ml. of water, and add 1.5 ml. of hypochlorite solution and 1 ml. of 20 percent sulfuric acid (by weight). Chlorine is evolved and the material frequently turns yellow. After standing for 10 minutes (with occasional stirring) protected from direct sunlight, filter and treat with sulfite solution as before. An intense purple coloration is noted, indicating the presence of lignin. Continue the ethanolic sodium hydroxide washings and the acid hypochlorite treatments as long as a positive reaction for lignin is given on addition of sulphite. After the final boiling with sulphite, filter and wash with 50 ml. of hot distilled water and transfer the cellulose to an alundum crucible and wash several times in the crucible with hot water. Dry at 105° to 110°C. and determine the cellulose by the weight loss on ignition.

Discussion of the Method

In the modified method, washing with 0.25 N sodium hydroxide in approximately 60 percent ethanol is used, although according to Norman and Jenkins (1933) all treatments should be carried out in neutral or near neutral solutions. However, the work of Giertz (1943) and Norman (1935) indicates that cellulosans are not extensively dissolved by dilute ethanolic alkali. A comparison of results (table 2) obtained on a variety of plants, both by the modified and by the Norman-Jenkins method, indicates that the use of ethanolic alkali is permissible. The use of ethanolic alkali shortens the procedure considerably and hence was adopted.

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connected to the vacuum line at the top by rubber tubing and joined at the bottom with a short section of rubber tubing to the filter stick. The purpose of the side arm is to facilitate the introduction of liquids into the inside of the filter stick for thorough washing off of solids from the fritted disk. Since the authors have found that about one-third of the filter sticks as purchased are unsatisfactory, it is advisable to purchase more than needed and discard those that do not filter well. The filter sticks are coated with pre-ashed diatomaceous earth (hyflo Supercel, Johns-Manville, N. Y., N. Y.) by suspending some in water and sucking on a thin layer with vacuum. This usually is sufficient for easy filtration; if not, extra Supercel added to the residue being filtered will often help.

[3] The normality of either the acid or alkali need be only approximate providing the end point is in the range of pH 7 to 9.

[4] Chlorox sold in most grocery stores is satisfactory.

The lignin content of the cellulose obtained from a sample of timothy hay by these two methods was found to be the same (2.6 percent). Twenty-four cellulose determinations can be made per day with the modified procedure described.

An important advantage of this method is that the time for each treatment need not be exact. The specified time of ten minutes for the chlorination treatment may be extended to twenty minutes with no harm. Moreover, an extra chlorination after a negative lignin test is given with sodium sulphite apparently does not appreciably affect the cellulose values obtained as is indicated by the following data:

TABLE 2. A COMPARISON OF THE MODIFIED METHOD AND THE NORMAN-JENKINS METHOD

Sample	Modified method		Norman-Jenkins method	
	% ash-free cellulose	No. of treatments	% ash-free cellulose	No. of treatments
Oat clippings	19.20*	1N–2A**	19.34	2N–2A
Sudan grass before heading	33.02	1N–2A	33.92	2N–2A
Corn stover	32.03	1N–2A	32.79	2N–3A
Timothy hay	40.22	1N–3A	41.72	2N–4A

* The mean value of duplicates is given.

** N=neutral hypochlorite. A=acid hypochlorite.

Sample	*3 Chlorinations*	*4 Chlorinations*
Sudan grass	40.3%	40.3%
Rabbit feces	51.6%	51.1%

The average percentage variation between duplicates for 4 samples of sudan grass and 11 samples of rabbit feces was ± 0.73 percent. Only one sample of the 15 gave a percentage variation between duplicates greater than 1 percent.

The Cellulose Content of Some Grasses and Legumes

In table 3 are shown the crude fiber and cellulose contents of 3 grasses and of 3 legumes which were harvested for hay. Since crude fiber content is an approximate measure of true cellulose, it is interesting to note that with the legumes the agreement between crude fiber and cellulose is relatively close, while with the grasses the cellulose values are greater by approximately 30 percent, thus indicating that these grasses contain more xylan than do the legumes.

A review of the literature substantiates the view that grasses and legumes

TABLE 3. A COMPARISON OF CELLULOSE AND CRUDE FIBER IN SOME LEGUME AND GRASS HAYS

Material	Crude fiber	Cellulose
	percent	*percent*
Sudan grass before bloom	30.5	39.8
Timothy hay	30.0	40.2
Rye	31.6	40.8
Lespedeza	30.0	31.0
Soybean	32.0	29.8
Canada field pea	32.8	29.5

differ markedly in xylan content. Buston (1935) showed that the bean leaf, bean pod, and sweet pea contain little or no xylan, while grass, maize, and wheat bran contain 20 percent or more. Norman (1935) also found that the xylan content of cellulose isolated from the wheat plant is higher than that isolated from vetch. The available data (Phillip and Goss, 1935, Norman and Richardson, 1937, and Norman, 1939) demonstrate that at least one-half

TABLE 4. THE COMPOSITION OF VARIOUS PLANTS AT DIFFERENT STAGES OF GROWTH. (ON DRY MATTER BASIS)

Sample period	Crude fiber	Cellulose	Lignin
Soy Beans (planted 5-4-44)			
	percent	*percent*	*percent*
6- 4-44	17.94	19.57	4.04
6-19-44	28.98	28.57	7.33
7-27-44 (hay stage)	34.79	32.43	8.31
9- 2-44	36.48	33.56	9.78
Canada Peas (planted 5-5-44)			
6- 3-44	16.78	18.26	3.74
6-19-44	26.61	26.55	5.61
7-13-44 (hay stage)	29.28	28.14	7.08
7-27-44	32.23	32.96	7.83
Rye Grass (from Norman, 1936a)			
4-26-36	18.76	20.89	4.63
5-10-36	18.17	20.45	4.37
5-24-36	17.08	23.15	5.08
6- 7-36	21.54	29.69	6.30
6-21-36	26.34	36.30	8.48
Hay	31.60	40.85	9.32

of the furfuraldehyde yield of grass forages arises from cellulosan xylans. Therefore, Bennett's work (1940) showing that blue grass forage yields twice as much furfuraldehyde as red clover furnishes additional evidence that grasses and legumes differ in xylan content.

The differences in the cellulose content of the grasses and legumes in table 3 are important in livestock feeding if the differences fall in line with feeding value. The following data obtained with digestion trials on 22 sheep indicate that the cellulose value is a better index of feeding value than the crude fiber value:

Feedstuff	*Crude fiber, percent*	*Cellulose, percent*	*Digestibility of organic matter, percent*
Sudan grass before bloom	30.5	39.8	62.5
Canada field pea hay	32.8	29.5	70.0

In table 4 are presented data showing the changes in crude fiber, cellulose, and lignin content throughout the growing season of two legumes and a grass forage. The grass data was taken from Norman's work (1936a). The crude fiber and cellulose content of the legumes increase at practically the same rate. On the other hand, the cellulose content of the grass increases at a faster rate than the crude fiber content as the grass matures. Accordingly, the crude fiber value becomes increasingly less reliable as an index of the poorly digested carbohydrate fraction of grass forages with advancing maturity.

Summary

A modification of the Norman-Jenkins (1933) method for the determination of cellulose in plants and in feedstuffs is described.

Analyses of various legumes and grasses are given which indicate that this method has certain advantages over other methods for estimating the relatively indigestible carbohydrate fraction of feedstuffs.

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INDUCTION OF MATING AND LAMBING IN ANESTROUS EWES FOLLOWING PREGNANT MARE SERUM ADMINISTRATION[1]

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Introduction

SHEEP have a rather definite breeding season. Ewes come into estrus the latter part of August or the first part of September, and in the absence of pregnancy, estrus will recur about every sixteen days (McKenzie and Terrill, 1937) until December or January. The period from February to August, the time of sexual inactivity, is referred to as the anestrous period. The discovery (Cole and Hart, 1930) of a potent gonadotrophic hormone in the blood of pregnant mares has led to a considerable amount of research work on the possibility of augmenting fertility in sheep by hormonal administration. The literature on the subject has been reviewed by Phillips, Fraps, and Frank (1945). Since the appearance of that review, two additional papers have been noted. Cole, Hart, and Miller (1945) gave a single injection of equine gonadotrophin (a pregnant mare serum preparation, hereafter referred to as PMS) to 118 anestrous ewes. Eight came into estrus within a 10-day period and all mated; however, none became pregnant. The force-mating of 18 ewes after a single injection of PMS resulted in no pregnancies. Fifty-eight of 170 ewes given two injections of PMS at 17-day intervals came into estrus but only 17 of the 53 which were mated conceived. Koger (1945) reported that seven of 46 ewes, which received either PMS or a crude pituitary extract during the breeding season and were inseminated on the second and/or third day following, lambed as a result of induced ovulation. One of two anestrous ewes injected with PMS and force-mated two days later lambed as a result of treatment.

If PMS is to have a place in sheep raising it must have the effect, when given either alone or in conjunction with another hormone, of inducing estrus, and ovulation in the anestrous ewe, and with a high proportion of conceptions following mating. This work was carried out in an attempt to determine what percentages of anestrous ewes will lamb following PMS therapy. In some of the groups it was possible to obtain the lambing records of the ewes following the lambings resulting from PMS therapy.

Materials and Methods

One hundred and seventy-seven anestrous ewes and 10 rams were the

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TABLE 1. THE INFLUENCE OF PREGNANT MARE SERUM IN ANESTROUS EWES

Group	Initial injection			Second injection			Total mated	Total not mated	Number lambed			Subsequent lambing record[4]		
	No. of ewes	Date	No. mated	Ewes treated	Date	No. mated			Initial inject.	Second inject.	Total lambed	No. of ewes	First	Second
Spring '42 Group 1	10	4/6/42[1]	—	10	4/22/42[1]	10	10	—	—	6	6[3]	5	May '43	Jan. 44
Spring '42 Group 2	25	4/26/42[1]	11	14	5/12/42[1]	7	18	7	2	3	5	5	May '43	Feb. '44
Spring '43 Group 3	12	5/ 7/43[1]	—	12	5/23/43[1]	10	10	2	—	5	5	5	July '44	Apr. '45
Spring '43 Group 4	2	5/ 7/43[1]	2	—	—	—	2	—	1	—	1	1	July '44	Apr. '45
Spring '43 Group 5	12	6/ 8/43[1]	—	12	6/24/43[1]	10	10	2	—	10	10	5	Aug. '44	—
Spring '44 Group 6	74	4/28/44[1]	7	67	5/16/44[1]	53	60	14	—	29	29	—	—	—
Spring '45 Group 7	42	4/ 4/45[2]	2	40	4/20/45[2]	24	26	16	2	12	14	—	—	—
Totals	177	—	22	155	—	114	136	41	5	65	70	21	—	—
Percent	100	—	12.4	87.6	—	64.4	76.8	23.2	2.8	35.9	38.7	—	—	—

[1] Each ewe injected with 250 r.u. (PMS).
[2] Each ewe injected with 350 r.u. (PMS).
[3] One ewe died in August 1942, autopsy showed fetus.
[4] Of ewes which lambed as a result of injections.

experimental animals. The breeds of sheep employed are indicated under results. Anestrous ewes were injected subcutaneously with either 250 or 350 rat units of PMS (Gonadin[2]). Ewes not coming into estrus within 16 days after the initial injection received a second injection, usually on the 16th day. The rams were always injected subcutaneously with 500 rat units of PMS about one week before the ewes were injected. The chests of the rams were painted, and ewes with well-marked rumps were recorded as having mated. Lambing dates were recorded and since all ewes were ear-marked it was possible to determine whether they had received one or two injections of PMS.

Results and Discussion

On April 6, 1942, ten aged Hampshire ewes (group 1) each received 250 rat units of PMS. None of the ewes showed signs of estrus and they were reinjected, therefore, with a similar dose of PMS 16 days after the initial injection. Within ten days after the second injection all of the ewes had mated. One of the ewes died in August, and an autopsy revealed a normal fetus. Five of the ewes lambed in the fall, resulting in a 60 percent[3] lamb crop.

The five ewes that lambed mated again the latter part of December and lambed in the late spring of 1943. The lambs were weaned in August and in the fall each of the five ewes mated during the normal breeding season and lambed in January 1944.

Group 2, consisting of 25 three-quarter bred Dorset yearlings, were each injected with 250 rat units of PMS on April 26, 1942. Eleven of the 25 mated, and the remaining 14 received a second injection, as a result of which seven additional ewes mated. Thus a total of 18, or 72 percent, came into estrus. Five of the ewes, or 20 percent of the total number injected, lambed in the fall of 1942.

The five ewes that lambed following PMS treatment mated late in December and lambed in the spring of 1943. After this second crop of lambs was weaned, the five ewes mated again during the normal breeding season and they lambed in February, 1944.

The ewes in the third group were 12 of the 15 three-quarter bred Dorsets that either mated but did not conceive or failed to mate following PMS treatment in the spring of 1942. Each of these 12 ewes received 250 rat units of PMS on May 7, 1943. None of the ewes mated following the injection, and 16 days later they received an additional 250 rat units of PMS.

[2] The pregnant mare serum used in this work was generously supplied by the Cutter Laboratories, Berkeley, California, through the courtesy of Dr. D. H. Wonder.

[3] This 60 percent includes the ewe which died and which upon autopsy showed a normal fetus.

By the tenth day, 10 of the 12 ewes, or 83 percent, had mated. Five of these ewes, or 41 percent of the total number which were injected, lambed in October, 1943.

The October lambs of the five ewes were weaned in January 1944, and by February 1, 1944, each one of the ewes had mated. All of them lambed in July, 1944. These same ewes mated again during the latter part of the normal breeding season, and they lambed in April 1945.

Group 4 consisted of two purebred Cheviot ewes. They were actually a part of group 3 but were kept separate since they were a different breed. Both ewes received 250 rat units of PMS apiece, and within four days of injection they had mated. One lambed in October 1943, and she lambed in July 1944 and again in April 1945.

The fifth group consisted of 4 aged purebred Cheviots and 8 three-quarter bred Dorset ewes. Each ewe received 250 rat units of PMS on June 8, 1943. As none of the ewes mated, each received a second injection of 250 rat units of PMS on June 24, 1943. Ten of the injected ewes, or 83 percent, mated and lambed in November 1943. Therefore, 100 percent of those that mated also lambed.

The lambs were weaned in February 1944 and by March all of the ewes had remated, though only five lambed in August 1944.

Group 6 consisted of 74 grade Dorset ewes. These ewes each received 250 rat units of PMS on April 28, 1944. Seven mated following this single injection. The remainder were given a similar injection on May 16, 1944. Fifty-three of them mated, making a total of 60 out of 74, or 81 percent that mated following either one or two injections of PMS. Twenty-nine of the group lambed in October 1944. Therefore 39 percent of the injected ewes and 48 percent of the mated ewes lambed. It was not possible to follow this group through for subsequent lambings.

In the last group (group 7) 42 grade Dorset ewes were each injected with 350 rat units of PMS on April 4, 1945. Two ewes mated, and the remainder received a similar dose of PMS on April 20, 1945. Twenty-four of the latter group came into estrus and mated. Of the mated ewes, two that received one injection and 12 that received two injections lambed during September. On the basis of the number of ewes injected, 62 percent mated and 33 percent lambed.

No ewes remained uninjected; however, the injections were made at a time when ewes rarely come into estrus. Of a total of 177 ewes used in the experiments reported, 77 percent came into estrus and mated, 12 percent after the initial injection and 64 percent after a second injection, which was usually made 16 days after the first injection. Only 39 percent of the treated ewes lambed. The results of the several groups are variable. On the basis

of the number of ewes injected, the percentage of those mating varied from 61.9 to 100 and the percentage of those lambing varied from 20 to 100. On the basis of the number of injected ewes that mated, the percentage of those lambing varied from 27.7 to 100 percent.

A difference in response among the seven groups is to be expected, since a number of variables were present in the work. Injections were made in four different years, and the ewes varied with respect to age and breed. The young animals did not respond as well as the older animals. Group 2, which consisted of 25 animals approximately 15 months of age, was the least responsive of the seven groups. The physical condition of the ewes also appeared to be a factor affecting response. The lambs had been weaned recently from a majority of the ewes in group 7 and the ewes were not well conditioned. In this group 33.3 percent of the injected ewes lambed whereas in group 6, a group consisting of well-conditioned ewes, the percentage of injected ewes lambing was 39.1.

A single injection of PMS induced estrus in a low percentage of the cases; however, a fairly high percentage of ewes mated following the second injection. It seems possible that ewes responding to a single injection of PMS are those whose ovaries are still functioning but not producing sufficient estrogen to induce an estrous condition. The injected PMS then brings about a greater ovarian stimulation, which in turn results in greater estrogen production.

Summary

One hundred and seventy-seven anestrous ewes received either one or two injections of PMS (250–350 rat units). One hundred and thirty-six came into estrus and mated, 22 following a single injection and 114 following a second injection which was usually made 16 days after the initial injection. Seventy ewes lambed, five of which received one injection and 65 of which received two injections.

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EFFECTS OF SOME ENVIRONMENTAL FACTORS ON WEANLING TRAITS OF RANGE COLUMBIA, CORRIEDALE AND TARGHEE LAMBS

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BREEDING investigations are being conducted at the U. S. Sheep Experiment Station at Dubois, Idaho, with the aim of improving meat and wool production in Columbia, Corriedale and Targhee sheep, all of which are descended from crosses of long-wool and fine-wool breeds. Stringent culling is practiced soon after weaning, at which time several environmental factors, quite apart from genetic merit, may have influenced the apparent worth of the lambs.

Phillips and Dawson (1937, 1940) found that the selection of Hampshire, Shropshire, and Southdown lambs under farm conditions of the eastern United States was affected by type of birth, time of birth, and birth weight of lambs. Donald and McLean (1935) in New Zealand and Bonsma (1939) in South Africa reported that the growth rate of several breeds and breed crosses was strongly influenced by sex, age of dam, and twinning. Starke (1945) in South Africa found differences in type and finish due to sex and twinning. Hazel and Terrill (1945) working with Rambouillet lambs under range conditions in the United States, found that nearly all of the environmental factors studied had important effects on one or more weanling traits.

The purpose of the present study was to measure the importance of sex, age of dam, type of birth, age at weaning and percent inbreeding on several weanling characteristics in Columbia, Corriedale and Targhee lambs produced under Intermountain range conditions of the western United States. The traits studied were weaning weight, staple length, body type, condition (degree of fatness), face covering, and neck folds. Although not considered as of environmental origin, breed differences were measured in the present study and are consequently reported.

Description of Data

The data used in this study were taken on 478 Columbia, 238 Corriedale and 366 Targhee lambs in 1941 and 1942. Since all of the lambs weaned were included in the study, the data are free from the effects of selection except for death losses prior to weaning. Weanling records were taken by experienced animal husbandmen at or near weaning at which time the lambs were an average of 120 days in age. A committeee of two or three men

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working independently gave each lamb scores for body type and neck folds. A second committee scored face covering and measured staple length at the middle of the side, while an additional man assigned scores for condition (degree of fatness) by feeling along the back and ribs. The scoring system was the same for the four traits evaluated by scoring; lambs considered as having the highest merit were given a score of 1 and those having poorest merit a score of 5. Fifteen scoring units were obtained by assigning plus and minus values to the scores for lambs that appeared to be slightly above or below a whole unit.

The method of statistical analysis was similar to that suggested by Yates (1934) for the analysis of multiple classifications with unequal subclass numbers, usually designated as the method of fitting constants. The method, described elsewhere by Hazel (1946), is designed to eliminate inequalities due to the various classifications by least squares procedure, thus providing unbiased estimates of the differences due to sex, age of dam, type of birth and breed, and of the regression coefficients on age at weaning and percent inbreeding.

Results and Discussion

The pertinent information concerning differences in each of the six characteristics is summarized in tables 1, 2 and 3. Table 1 shows the means, standard deviations within classes, differences in main effects and the regression coefficients on age and percent inbreeding. It should be noted that negative differences reflect superior merit in the four traits evaluated by scoring, since the magnitude of the scores given decreased as merit increased. The analyses of variance and tests of significance are given in table 2 and the breed differences in table 3. The average age of the lambs was 120 days and the average inbreeding was 9.74 percent.

Weaning Weight

At weaning ram lambs averaged 10.8 pounds heavier than ewe lambs, and lambs from mature dams were 8.7 pounds heavier than those from 2-year-old dams (table 1). Single lambs weighed 11.7 pounds more than twin lambs and 5.1 pounds more than twins raised singly. All of these differences are about 2.5 pounds greater than corresponding differences in Rambouillets reared under comparable management (Hazel and Terrill, 1945). The lambs were growing at an average rate of 0.448 pound per day, as indicated by the regression of weight on age at weaning. This rate is higher than the figures indicated in studies by Phillips and Brier (1940), Phillips, Stoehr and Brier (1940), and Hazel and Terrill (1945), but the lambs in the present study were heavier than those of the other studies. The regression of weaning weight on

percent inbreeding was −0.302 pound, some of which may be due to the inbreeding of the dams rather than of the offspring, since the more highly inbred lambs were usually from dams with more than average inbreeding.

Table 2 shows that all the factors had highly significant effects upon weaning weight. Since about 33 percent of the total variations in weaning

TABLE 1. MEAN, STANDARD DEVIATION WITHIN CLASSES, DIFFERENCES DUE TO THE SEVERAL FACTORS AND REGRESSION COEFFICIENTS FOR EACH OF THE SIX TRAITS

Statistic	Weaning weight	Staple length	Body type	Condition	Face covering	Neck folds
	pounds	*centimeters*	*score*	*score*	*score*	*score*
Mean	73.0	4.40	2.20	2.15	3.18	1.14
Standard deviation	10.3	0.69	0.45	0.51	0.50	0.36
Ram minus ewe	10.8*	−0.54*	0.30*	0.11	0.06	0.14*
Mature minus 2-year-old dam**	8.7*	0.52*	−0.25*	−0.26*	−0.07	0.05
Single minus twin	11.7*	0.02	−0.38*	−0.28*	−0.17	0.05
Single minus twin raised singly	5.1*	0.31	−0.17*	−0.16*	−0.05	−0.07
Regression on age at weaning	0.448*	0.014	−0.020*	−0.016	−0.018	−0.012*
Regression on percent inbreeding	−0.302*	0.000	0.009*	0.007	−0.001	−0.003

* Signifies that the statistic is large enough to account for 2 percent or more of the total variation.
** Mature dams were 3 years old and older.

weight could be attributed to their effects, it is evident that controlling or adjusting for them will increase accuracy appreciably in selecting for greater weight at weaning.

Length of Staple

In staple length ewe lambs average 0.54 cm. more than ram lambs, only a slightly larger difference than was found in Rambouillets. Lambs from mature dams had a staple 0.52 cm. longer than lambs from 2-year-old dams. Single lambs had a slightly longer staple than twin lambs, and the latter had a longer staple than twins raised singly, but type of birth was not an important source of variation. Although staple length must increase at an average rate of about 0.035 cm. per day to attain the observed average of 4.40 cm. in 120 days, the regression of staple length on age was only 0.014

cm. Since a similar discrepancy was observed in Rambouillets, it seems certain that length of staple as measured in these lambs did not increase linearly with age. This problem, as well as the origin of the sex differences mentioned above, might be clarified if successive measurements of staple length and fiber length were taken on a group of lambs at relatively short intervals from birth to weaning or yearling age. Staple length was not affected by percent inbreeding to any measurable extent.

Table 2 shows that all the environmental factors except percent inbreeding had highly significant effects upon staple length. Although about 12

TABLE 2. SUMMARY OF ANALYSIS OF VARIANCE FOR EACH OF SIX TRAITS (MEAN SQUARES ONLY)

Source of variation	Degrees of freedom	Weaning weight	Staple length	Body type	Condition	Face covering	Neck folds
Total	1081	174	0.87	0.26	0.29	0.39	0.14
Sex	1	20,988**	52.33**	16.48**	2.35**	0.64	3.39**
Age of dam	1	13,263**	47.70**	10.96**	12.27**	0.87	0.52*
Type of birth	2	8,146**	5.80**	8.66**	4.79**	1.74**	0.60**
Age of weaning	1	4,690**	4.72**	9.78**	5.65**	7.61**	3.45**
Inbreeding	1	6,459**	0.06	5.92**	3.84**	0.05	0.50*
Breeds	2	8,638**	154.27**	1.42**	4.36**	63.52**	3.40**
Error	1073	106	0.48	0.20	0.26	0.25	0.13

* Signifies probability of chance occurrence $<.05$.
** Signifies probability of chance occurrence $<.01$.

percent of the total variation could be attributed to the environmental factors, only differences due to sex and age of dam were quantitatively large enough to require adjustment.

Body Type

Ram lambs were scored 0.30 poorer in body type than ewe lambs. The ewe lambs and ram lambs were scored on different days in both 1941 and 1942 and the sex difference may have resulted from a higher standard for ram lambs. Lambs from mature dams were scored 0.25 better than lambs from 2-year-old dams, while single lambs excelled twins raised singly or twins raised as twins. Starke (1945) and Hazel and Terrill (1945) observed similar differences in sex and type of birth in other breeds. Type scores were better for the older lambs, and poorer for the more highly inbred lambs, as judged by the regressions of type score on age and percent inbreeding.

Differences due to sex and type of birth were quantitatively the most important sources of variation which affected scores for body type, although all the factors were statistically significant. The total reduction attributed to all the factors was about 22 percent of the total variation.

Condition

Ram lambs on the average were scored 0.11 poorer in condition than ewe lambs, although the ram lambs were considerably heavier at weaning (table 1). Lambs from mature dams and single lambs were scored better than those from 2-year-old dams and twin lambs, respectively. As indicated by the regression coefficients, the lambs became better in condition with increasing age and poorer with inbreeding. The differences in condition score were very similar to those in type score, except for the sex difference. It may also be noted that, except for sex, the several factors had effects on type and condition which were in the same direction and of approximately the same magnitude as those for weaning weight.

Although all the differences were large enough to be statistically significant (table 2), only age of dam and type of birth were important quantitatively. About 11 percent of the total variation in condition could be attributed to the factors studied.

Face Covering

Ram lambs had only slightly more wool covering over the faces than ewe lambs, whereas a marked sex difference existed in the more heavily wooled faces of Rambouillets (Hazel and Terrill, 1945). Only type of birth and age at weaning had significant effects upon face covering. Faces became less covered as age increased, the regression being −0.018. All the environmental factors studied accounted for only 3 percent of the total variation, and little information would be sacrificed if no adjustments were made for environmental effects upon face covering.

Neck Folds

Neck folds were more heavily developed in ram lambs, lambs from mature ewes and single lambs than in ewe lambs, lambs from 2-year-old ewes, and twin lambs, respectively. These differences may be due to the fact that the development of folds is reduced on a low plane of nutrition and augmented on a high plane, as found by Carter (1941) in Merinos. Except for age at weaning, the remaining factors had little effect upon neck folds. Neck folds decreased as age increased, the regression being −0.012.

Six percent of the variation in neck folds was attributed to the environmental factors. Only the differences due to sex and to age were large enough to warrant adjustment.

Breed Differences

It is well known that breed differences are not exactly constant over a wide range of environmental conditions, the variation being much greater in some characteristics than in others. The differences given in table 3 for Columbia, Corriedale and Targhee lambs were obtained on lambs that were herded in the same flocks under Intermountain range conditions near Dubois, Idaho in 1941 and 1942.

The Columbia lambs were heavier and were scored better in body type and condition than Corriedale lambs. They had less wool covering over the

TABLE 3. DIFFERENCES BETWEEN BREED AVERAGES FOR THE SIX TRAITS

Breed differences	Weaning weigt	Staple length	Body type	Condition	Face covering	Neck folds
	pounds	*centimeters*	*score*	*score*	*score*	*score*
Columbia minus Corriedale	8.8**	−0.93**	−0.12**	−0.23**	−0.32**	0.07*
Columbia minus Targhee	7.2**	0.53**	−0.08**	−0.09*	−0.79**	−0.14**
Targhee minus Corriedale	1.6	−1.46**	−0.04	−0.14**	0.47**	0.21**

* Signifies probability of chance occurrence $< .05$.
** Signifies probability of chance occurrence $< .01$.

faces, but were considerably shorter in staple and had slightly more neck folds than Corriedales. The Columbia lambs exceeded the Targhees in each of the six characteristics, the differences showing they were heavier in weight and longer in staple, had higher type and condition scores, and were freer from wool blindness and neck folds. The Targhee lambs were slightly heavier than Corriedales and exceeded them in type and condition scores but were much shorter in staple and had more heavily wooled faces and more neck folds than Corriedales.

Application of Results

Progress in animal improvement through selection is limited because only part of the variation in most traits is caused by genetic differences. The remainder of the variation, caused by environmental differences, may be partially adjusted or corrected if the effect of some environmental factors can be measured. Thus, the animal breeder has the opportunity of increasing progress expected from selection insofar as he can accurately compensate for the effects of known inequalities in environment.

Adjustment of weanling traits for environmental influences in the breeds

of sheep studied here is most important for body weight and body type. Some increases in accuracy of selection may be obtained by adjusting records of staple length and condition score but little is to be gained by adjusting scores for neck folds and face covering. The least work is involved by adjusting the smaller groups to the largest group. For example, the effect of age of dam can be minimized by adding 8.7 (or 9) pounds to the weaning weight and 0.52 (or 0.5) cm. to the staple length of lambs from 2-year-old ewes. If a selection index or total score including several traits is used a single correction for each factor can be added directly to the index instead of making a separate correction for each of the several traits.

Most sheep breeders may not be able to keep or analyze records to the extent necessary to make adjustments for environmental effects. They may obtain similar results by running early and late lambs, single and twin lambs, and lambs from mature and 2-year-old ewes in different bands and by making selections before the lambs from the different bands are mixed. An alternate method consists of sorting the lambs into these groups at weaning time and selecting the same proportion from each group. If this is not feasible selection for body weight and type might best be postponed until yearling age when these environmental factors are less important.

Summary

The effects of sex, age of dam, type of birth, age at weaning and percent inbreeding were studied on 478 Columbia, 238 Corriedale and 366 Targhee lambs raised in 1941 and 1942 at the U. S. Sheep Experiment Station, Dubois, Idaho.

Differences in weaning weight between ram lambs and ewe lambs, lambs from mature and 2-year-old dams, and single and twin lambs were 10.8, 8.7 and 11.7 pounds, respectively. Ewe lambs, lambs from mature dams, and single lambs had longer staple and were given higher type and condition scores than the contrasting groups. Face covering and neck folds were not strongly influenced by any of the factors. Merit in each of the traits increased with age at weaning, as indicated by regression coefficients. Inbreeding had a noticeably detrimental effect upon weaning weight, body type and condition, but not upon length of staple.

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NEWS AND NOTES

The next annual meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago on November 29 and 30, 1946. Abstracts of papers to be presented at the meeting must be in the hands of the Secretary, Dr. W. G. Kammlade, by September 10. Abstracts must not exceed 250 words in length (about one page, typed, double spaced). Please see item 9 of "Information for Contributors" for instructions on preparation and typing of abstracts.

The preparation of complete and up-to-the-minute "News and Notes" sections in the JOURNAL would be greatly facilitated if all department heads would advise the Editor promptly of changes in their staffs, and if each member would promptly advise the Editor of any change in his position or any other item of professional interest concerning himself. The constant cooperation of all members in this matter will be much appreciated.

The following have returned to their former positions, after periods of duty in the armed forces: Ural G. Bee, extension animal husbandman at the University of Maryland; Charles E. Bell, Jr., extension animal husbandman, University of Georgia Extension Service; John A. Gorman, animal husbandry department, University of Wyoming; Wayland Rhoads, extension animal husbandman, University of Kentucky.

A. H. Groth of the Louisiana Agricultural Experiment Station, has been appointed director of the Regional Animal Disease Laboratory, Auburn, Ala., succeeding B. T. Simms who recently became chief of the Bureau of Animal Industry.

O. Burr Ross, formerly of the University of Wisconsin, has returned from military service and accepted a position with the Oklahoma A & M College.

H. W. Hilston formerly of the University of Arkansas is now with the animal production department at the University of Wyoming.

Gordon C. Winn, former county agricultural agent at Craig, Colorado, was appointed extension animal husbandman (sheep and wool) at the Colorado State Agricultural College, effective February 1.

John C. Burns was made executive secretary and manager of the American Quarter Horse Association, with headquarters at Fort Worth, Texas, effective April 15.

William E. Sewell of the Alabama Polytechnic Institute has resigned to engage in commercial work.

Walter D. Armer was appointed extension animal husbandman, University of Arizona, effective March 1. He succeeds his brother, Frank C. Armer, who resigned last fall.

Edward L. Lowder, formerly in county agent work, was appointed meat animal specialist in the Alabama Extension Service, effective May 1.

T. B. Keith, assistant professor of animal husbandry, Pennsylvania State College, has resigned to accept a similar position at the Montana State College and Experiment Station.

J. McK. Jeter has been appointed assistant extension animal husbandman in the Clemson (S. C.) Agricultural Extension Service.

James J. O'Connell has been appointed extension animal husbandman in South Dakota, with headquarters at Brookings.

Graydon Blank, formerly in vocational agriculture work, has been made assistant extension animal husbandman with the Michigan Extension Service at East Lansing.

Hubert Jones, former assistant county agent in Indiana, was made assistant extension animal husbandman with the Indiana Extension Service, effective April 1.

H. D. Elijah, who was with the Missouri State Department of Agriculture and in the Medical Corps of the U. S. Army, is now director of the livestock service division of the Wilson and Co. plant at Oklahoma City, Oklahoma.

E. S. Good, retired head of Kentucky's animal industry department, was made "Man of the Year" for Kentucky by the Progressive Farmer for 1945.

W. H. Tomhave has announced that he will retire as secretary of the American Aberdeen-Angus Breeders' Association, December 31, 1946.

V. A. Rice of Massachusetts State College received the honorary degree of Doctor of Agriculture from North Carolina State College on June 3, 1946.

The Hawaii Agricultural Experiment Station has openings for two men, as follows: Assistant Animal Husbandman (with not less than two years of graduate study), and Junior Animal Husbandman (with not less than one year of graduate study). Initial salary depends somewhat on training and experience. Anyone interested should contact Professor L. A. Henke, University of Hawaii, Honolulu, T. H.

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